2.0 SPECIES AND HABITAT COVERAGE

Jones and Stokes (1999) documented a number of criteria for selecting the species and habitats that are proposed for inclusion in King County's Wastewater Treatment Division's HCP. A total of 127 species are under consideration for inclusion in the HCP, and the subset of 41 species that inhabit the marine areas of the HCP Study Area are discussed in this report. The 41 marine species discussed in this report can be broken down into seven groups. These include:

- Marine Mammals and Birds 6 species
- Salmonids 7 species
- Lampreys 2 species
- Marine Invertebrates 2 species
- Ground Fish 6 species
- Forage Fish 4 species
- Rockfish 14 species

The species covered in this report are listed on the following page. Species which are currently listed under the U.S. Endangered Species Act (ESA) as threatened include the Steller sea lion, marbled murrelet, chum salmon (Hood Canal summer and Lower Columbia stocks), sockeye salmon (Lake Ozette stock), chinook salmon (Puget Sound, Snake River [spring, summer, fall], and Lower Columbia stocks), steelhead (Snake River, Middle and Lower Columbia stocks), and bull trout. Species that are currently listed as endangered under the ESA include sockeye salmon (Snake River stock), chinook salmon (Upper Columbia spring stock), and steelhead (Upper Columbia stock). Species that have been listed as a species of concern under the ESA include the harlequin duck, Pacific lamprey, and river lamprey. All remaining species have been included in this document as they are listed as a species of concern (candidate species status) by the Washington State Department of Fish and Wildlife (WDFW) and may receive federal status as a species of concern in the future.

As most of the species covered in the report are highly mobile and may migrate between Washington and British Columbia waters, the status of these species in British Columbia is provided. In 1999, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) listed the southern resident killer whale population as threatened.

Common Name	Scientific Name
Marine Mammals and Birds	
Killer Whale	*Orcinus orca*
Harbor Porpoise	*Phocoena phocoena.*
Steller (Northern) Sea Lion	*Eumetopias jubatus*
Common Murre	*Uria aalge.*
Marbled Murrelet	*Brachyramphus marmoratus.*
Harlequin Duck	*Histrionicus histrionicus*
Salmonids	
Bull Trout	*Salvelinus confluentus.*
Chinook Salmon	*Oncorhynchus tshawytscha*
Chum Salmon	*Oncorhynchus keta*
Coho Salmon	*Oncorhynchus kisutch*
Cutthroat trout	*Oncorhynchus clarki*
Sockeye salmon	*Oncorhynchus nerka*
Steelhead	*Oncorhynchus mykiss*
Lampreys	
Pacific Lamprey	*Entosphenus tridentatus*
River Lamprey	*Lampetra ayresi*
Marine Invertebrates	
Northern Abalone	*Haliotis kamtschatkana*
Olympia Oyster	*Ostrea conchaphila* (Formerly *O. lurida)*
Ground Fish	
Green Sturgeon	*Acipenser medirostris*
White Sturgeon	*Acipenser transmontanus*
Pacific Cod	*Gadus macrocephalus*
Walleye Pollock	*Theragra chalcogramma*
Pacific Hake	*Merluccius productus*
Lingcod	*Ophiodon elongates*
Forage Fish	
Pacific Herring	*Clupea harengus pallasi*
Sand Lance	*Ammodytes hexapterus*
Surf Smelt	*Hypomesus pretiosus*
Eulachon	*Thaleichthys pacificus*
Rockfish	
Brown Rockfish	*Sebastes auriculatus*
Copper Rockfish	*Sebastes caurinus*
Greenstriped Rockfish	*Sebastes elongates*
Widow Rockfish	*Sebastes entomelus*
Yellowtail Rockfish	*Sebastes flavidus*
Quillback Rockfish	*Sebastes maliger*
Black Rockfish	*Sebastes melanops*
Blue Rockfish	*Sebastes mystinus*
China Rockfish	*Sebastes nebulosus*
Tiger Rockfish	*Sebastes nigrocinctus*
Bocaccio Rockfish	*Sebastes paucispinus*
Canary Rockfish	*Sebastes pinniger*
Redstripe Rockfish	*Sebastes proriger*
Yelloweye Rockfish	*Sebastes ruberrimus*

Species also listed as threatened in British Columbia by the COSEWIC include the marbled murrelet and northern abalone. There are no HCP species that may occur in the study area listed as endangered by the COSEWIC.

A brief description of each species' life history, ecological role and environmental requirements is provided in Sections 2.1 through 2.5. These descriptions are general and are not meant to be detailed as more specific information can be found in other reference sources. The topics discussed are outlined below.

Life History	Ecological Role	Environmental Requirements
Spawning/Reproduction	Prey	Water depth
Larval Stages	Predators	Habitat
Juvenile Stages		Migration/Movement
Adult Stages		
Age at Maturity		
Gender Dimorphology		
Size		
Lifespan		

In some cases, information on these topics was not available. Finally, a general discussion of the marine habitats to be evaluated is presented in Section 2.6. The marine habitats discussed are located in the Central Puget Sound Basin, are utilized by the covered species, and extend from the deep subtidal (aphotic) zone to the supralittoral zone. Specific discussions of habitat characteristics in each of the three sub-areas are contained in Sections 3 through 5.

2.1 Marine Mammals and Birds

Three species of marine mammals and three species of marine birds are proposed for coverage in the HCP. The marine mammals include one member each of the dolphin family, the porpoise family, and the sea lion family. The marine birds include two members of the Alcid family and one member of the Anatid (waterfowl) family. Each of these is discussed below.

2.1.1 Dolphins – Family Delphinidae

There are over 30 species of dolphins worldwide, with most living in the oceans of the world. This family includes Orcas (killer whales), bottlenose dolphins, pilot whales, and Pacific white-sided dolphins. Delphinids have conical shaped teeth and a prominent dorsal fin, with the exception of one genus that has no dorsal fin. Members of this family also have either a prominent beak (bottlenose dolphins) or a short beak and a distinctly bulging forehead (Orcas). They

generally do not make prolonged deep dives and tend to frequent shallow waters and stay near the surface. They are considered fast agile swimmers and use echolocation to actively pursue fishes and squids. They may stun their prey with high-intensity sound (Yates 1998; Ridgway and Harrison 1998).

Orca – *Orcinus orca*

Life History. Orcas (killer whales) are widely distributed in the oceans of the world, although they prefer the colder waters of both hemispheres. Orcas have strong social bonds and travel together in stable groups, called pods, of up to 50 whales. In British Columbia and Washington State, pods have been identified as either 'transient', 'resident', or 'offshore' based on ecology, genetics, and behavior (Ford et al. 1994).

Male Orcas can reach a length of 9.5 meters (m) and can weigh in excess of 7,300 kilograms (kg) while females rarely exceed 7 m and 3,630 kg (Ridgway 1972; Leatherwood and Reeves 1983; Yates 1998). Females become sexually mature at about 10 years of age but do not typically calve until early teens and males reach sexually maturity at 12-14 years. Females may give birth as frequently as every three years, but typically calve every 8-10 years and stop calving around the age of 40 years. Gestation is thought to be between 16 and 17 months and calves are approximately 2.5 m in length and weigh 200 kg at birth (Ford et al. 1994). The calves nurse for a minimum of 1 year and may remain within their birth pod for their entire life. Orcas are known to live over 35 years, with maximum estimates of 60 years for males and 80 to 90 years for females. However, a typical life span is around 30 years for males and 50 years for females (Ford et al. 1994).

Ecological Role. Orcas are top predators with pronounced diet differences between Puget Sound resident and transient whales. Resident whales feed primarily on fish (salmon, lingcod, halibut, flatfish, greenling) and squid, with few observations of attacks on seals and porpoises. During spring through fall, the predominant prey item is salmon, with chinook being the most preferred (Ford et al. 1994; Everitt et al. 1980). Transient whales prey mostly on other marine mammals, including harbor seals, sea lions, and porpoises, but also prey on birds and fish (Ford et al. 1994; Dahlheim et al. 2000). They have no predators other than humans.

Environmental Requirements. In the Pacific Northwest, there are resident pods of whales that consist of extended families. The southern resident whale community consisting of three separate pods (designated J, K, and L) occasionally enter central Puget Sound, particularly the J pod. The J pod currently contains 19 whales; the K pod 17 whales, and the largest, L pod, contains 47 whales (A. Traxler, Whale Museum, pers. comm.). The distribution and movements of Orcas in central Puget Sound is directly related to prey abundance and/or the search for prey (Balcomb and Goebal 1976). If there is sufficient water for locomotion, there is no area in marine waters where the

whales will not enter in search of prey (Balcomb 1982). Transient whales are not known to enter inland Puget Sound waters.

Resident whales spend the majority of time (>70%) in the upper 20 m of the water column where salmon are concentrated. However, they occasionally dive to 100 m or more (a dive of 201 m has been recorded) when they are suspected to be feeding on bottom and mid-water fish (Baird et al. 1998).

2.1.2 Porpoises – Family Phocoenidae

There are six species of Phocoenids found in the coastal waters of all oceans and seas; two species are found in Puget Sound. Porpoises are small, with robust bodies that are generally less than 2.5 m in length (Leatherwood and Reeves 1983). Unlike dolphins, porpoises have spade shaped teeth rather than conical teeth and have a poorly defined beak, if one at all. Porpoises inhabit a variety of habitats including bays, estuaries, nearshore areas, and the open sea. Although large aggregations have been reported, porpoises tend to travel in small groups averaging less than twenty individuals (Leatherwood and Reeves 1983).

Harbor Porpoise – *Phocoena phocoena*

Life History. The harbor porpoise occurs in cold temperate and subarctic waters of the northern hemisphere and is the smallest porpoise found in the Pacific Northwest. Harbor porpoises were common throughout Puget Sound until their decline in the 1940's and now sightings south of the San Juan Islands and Strait of San Juan de Fuca are rare (B. Hanson, NMML, pers. comm.). The maximum length and weight is about 2 m and 90 kg and the average length is 1.5-1.6 m with a weight between 45-65 kg (Leatherwood and Reeves 1983). There is no size difference between males and females. Age at sexual maturity is estimated at 3-4 years and the principal mating season occurs between July and August (Ellis 1982; Palka et al. 1996). The gestation period is approximately 11 months with calves born every 1-2 years in late spring and early summer (Osborne et al. 1988). Calves are between 70-90 centimeters and nurse for approximately 8 months (Everitt et al. 1980). The harbor porpoise is one of the shortest-lived cetaceans, with a maximum lifespan of 17 years but with few animals living to 10 years (Read and Hohn 1995). The harbor porpoise avoids vessel traffic and does not ride bow waves, unlike some other porpoises and dolphins. These porpoises have a high metabolic rate that requires them to consume at least 10 % of their body weight daily, which creates a high oxygen demand (Read and Gaskin 1985). Consequently, harbor porpoises must surface frequently to breath and may surface as often as 8 times per minute which limits their dives to fewer than 4 minutes (Harrison 1974). As a result, these porpoises are not deep divers and their high-energy demands restrict lengthy migrations and movements.

Ecological Role. Harbor porpoises feed on fish, squid, and shrimp but prefer schooling fishes, such as Pacific herring, smelt, walleye pollock, and Pacific whiting (Osmek et al. 1997; Leatherwood and Reeves 1983). Kelp or seaweed,

sometimes with herring eggs attached, has also been found in their stomachs (Ridgway 1972). Killer whales and sharks are known predators of the harbor porpoise (Leatherwood and Reeves 1983).

Environmental Requirements. There are two recognized harbor porpoise stocks: the Oregon/Washington Coast stock and the inland Washington stock. The inland Washington harbor porpoise stock occurs in British Columbia and Washington State waters but sightings are rare south of the San Juan Islands and the Strait of San Juan de Fuca (Calambokidis et al. 1992; B. Hanson, NMML, pers. comm.). This is primarily a coastal species and is frequently found in bays, estuaries, tidal channels, and nearshore areas (Forney et al. 1999; Leatherwood and Reeves 1983). They prefer water temperatures from 5 to 16°C (Ellis 1982). Seasonal movements follow prey availability and tend to be inshore to offshore, rather than north to south (Osborne et al. 1988). Harbor porpoises usually travel singly or in small groups of 2-6 individuals but occasionally large aggregations will be seen where prey is abundant and during the mating season (Osborne et al. 1988). Although harbor porpoises may be seen year round throughout their range, the largest concentrations are found in summer and early fall in the northern San Juan Islands (Osborne et al. 1988). Harbor porpoises are usually found in waters less than 200 m deep in the eastern North Pacific (Osmek et al. 1997).

2.1.3 Eared Seals – Family Otariidae

This family contains 14 species worldwide, two of which are found in Puget Sound. Otariids have small external ears and can use their rotating hind flippers to move quickly on land, which distinguishes them from the true seals. In the water, they use their long fore flippers to move themselves through the water while they steer with their hind flippers. Otariids range from 150 kg to 1,100 kg in size, with females much smaller than males. The size difference between males and females is common for pinnipeds that have polygynous breeding habits. Otariids form large congregations during the breeding season with males maintaining harems and vigorously defending their territories. Upon arrival at the breeding grounds and before mating, females give birth to young from the previous year's breeding season.

Steller (Northern) Sea Lion – *Eumetopias jubatus*

Life History. The Steller sea lion is found throughout the north Pacific rim and in the eastern Pacific ranges from Alaska to central California. This sea lion is the largest of the eared seals. Males may attain a maximum length of 3.3 m and weight of 1,120 kg but averages about 2.8 m and 566 kg. Females are much smaller with a maximum length and weight of 2.9 m and 350 kg, respectively, but average approximately 2.3 m and 263 kg (Reeves et al. 1992). Males reach sexual maturity at approximately 3-7 years of age but do not typically breed before they are 10 years old, as they cannot successfully defend a territory until this time. Dominant males will fast from 1-2 months while maintaining a

territory at a rookery (breeding and pupping area). Most females attain sexual maturity between 4 to 5 years of age (Reeves et al. 1992). Gestation is about 12 months (including a 3 month delayed implantation stage) and females give birth to a single pup annually (Burns et al. 1985). Pups are born between mid-May to mid-July and weigh between 16 and 23 kg (Reeves et al. 1992). Pups will nurse for approximately 9 days and then the mother will go to sea to feed and alternate nursing with 1-3 day feeding trips. Pups usually nurse for up to 1 year but may nurse for 2 years (Reeves et al. 1992). Males are not known to live longer than 18 years and information regarding lifespan of females was not readily available (Reeves et al. 1992).

Within Puget Sound, Steller sea lions are seen in small groups but at their haulout sites in northern Puget Sound and the outer Washington coast, they may occur in large aggregations of 100 or more individuals (Jeffries et al. 2000). They are often seen at haulout sites with California sea lions.

Ecological Role. Most of the diet information for Steller sea lions is for the Alaskan population and little is known about food habits and diet for this species in Washington State. One of the few studies conducted in Washington waters found the dominant prey item to be Pacific whiting. Other prey items included Pacific herring, spiny dogfish, skates, and smelt. This study also determined that although salmonids were preyed upon, they did not make up a significant portion of the diet (Gearin et al. 1999). Males have been known to occasionally prey on other pinnipeds, particularly northern fur seal pups (Osborne et al. 1988). Prey for Steller sea lions in British Columbia and Alaskan waters includes various flatfish, Pacific whiting, walleye pollock, rockfish, Pacific herring, salmon, squid, and octopus (Everitt et al 1980). Predators include sharks and killer whales (Mate and Gentry 1979).

Environmental Requirements. Although single animals can occasionally be seen in inland Puget Sound at any time, they are seen most often from early fall to early spring and seldom during the summer months (Jeffries et al. 2000; Everitt et al. 1980). The migration and abundance of Steller sea lions on the northern Washington coast appears to be strongly correlated with the availability of Pacific whiting (Gearin et al. 1999). Haulout sites are found on jetties, offshore rocks, coastal islands, and navigational buoys. In inland Puget Sound, Steller sea lions (1 to 2 individuals) can typically be seen on navigational buoys and a few individuals can also be found interspersed with California sea lions in the Everett Harbor area (M. Lance, WDFW, pers. comm.). The closest congregations (> 10 individuals) to Puget Sound are found at Tatoosh Island on the outer coast, Sombria Point and Race Rocks in the Strait of Juan de Fuca, and Sucia Island in the San Juan Islands. None of these areas are breeding rookeries (Osborne et al. 1988).

Steller sea lions forage mostly in nearshore areas and over the continental shelf at relatively shallow depths in the water column. However, they are capable of diving to deeper depths and a dive of close to 300 m has been recorded (Reeves et al. 1992).

2.1.4 Alcids – Family Alcidae

The family Alcidae has 23 species and includes auks, puffins, guillemots, murres, and murrelets. Alcids are diving seabirds that come ashore only to breed. They are found in northern oceans and breed as far south as Baja California. The sexes are similar and adults fly and walk poorly. In the water they use their feet for surface movement and their wings to swim underwater. They are migratory and gather in large colonies to breed. Alcids are pelagic but stay close to shore and catch their prey underwater. They lay their eggs on rocky ledges with little or no nesting material. Both parents care for the eggs and young birds (Parker 1982; Yates 1998).

Common Murre – *Uria aalge*

Life History. The common murre is a true seabird found in the northern hemisphere and is a permanent resident of the Washington coast. This species spends most of the year on open waters and only comes to shore to nest in breeding colonies during the months of June and July (Angell and Balcomb 1982). These birds reach a length of 41 cm, have short wings (approximately 20 cm) and tail feathers, and have their feet positioned close to the tail (Freethy 1987). As a consequence, they are poor fliers but excellent swimmers. They breed in large colonies on rocky cliffs on the Washington coast where each pair lays a single egg on bare rock. The egg incubation time ranges from 28-39 days during which time the male and female take turns brooding the egg constantly (Freethy 1987). The juveniles jump from the cliffs into the sea to join their parents approximately 3-3.5 weeks after hatching but are not able to fly until 50-70 days after hatching (Freethy 1987; Baron and Acorn 1997). During this time the chicks are susceptible to storms and predation (Alcorn 1978; McConnaughey and McConnaughey 1985). Most common murres do not breed until they are 5 years old and the lifespan has been estimated to be at least 25 years (Freethy 1987).

Ecological Role. The diet of the common murre includes small fish, worms, and other marine invertebrates such as crustaceans and molluscs (Ehrlich et al. 1988; Jewett et al. 1953; Terres 1987). Fishes are the dominant prey items, consisting primarily of sand lance, smelt, and capelin, with sand lance the preferred prey (Angell and Balcomb 1982). Information on murre predators was limited; however, predators include gulls (both on eggs and young) at the breeding colony and at sea before the chicks fledge. Although not direct predation, eggs of common murres are often dislodged from rocky ledges when panicked adults fly off the nest (Gaston and Jones 1998). Predators of colonial seabirds in general include avian predators such as bald eagles, peregrine falcons, gulls and land predators such as mustelids, mice, and foxes (Gaston and Jones 1998).

Environmental Requirements. Although a resident of Washington's coast, these birds do not breed in Puget Sound and appear in the Sound in late summer and fall as the coastal colonies disperse (Angell and Balcomb 1982). This cross migration of Puget Sound occurs with the coastal breeding in summer months.

Common murres feed by diving under the water to catch their prey. Common murres will typically dive to a depth of 20-30 m to feed upon small schooling fish and have been recorded to a maximum dive depth of approximately 167 m (Ehrlich et al. 1988; Yates 1998). The common murre spends most of its time in open water and comes to shore only to breed. Their nesting habitat can be found along rocky cliffs. They migrate, in some cases hundreds of miles, to over-wintering areas, including Puget Sound, after the young fledge and leave the breeding colonies (Baron and Acorn 1997).

Marbled Murrelet – *Brachyramphus marmoratus*

Life History. The marbled murrelet is a small seabird that occurs in the Pacific from Alaska to southern California (Nelson 1997). This species spends most of its life on the ocean and nearshore marine waters but moves inland to nest in trees in older, coastal forests. In Puget Sound, marbled murrelets nest inland, often in large conifers that are most often associated with old growth forests (Angell and Balcomb 1982). At higher elevations they may also use ground burrows for nesting. Marbled murrelets do not reach sexual maturity until their second year and there is no difference in size between the sexes. They nest inland from mid April to late September and lay one egg. The incubation time is approximately 30 days, with about 28 days to fledge. After nesting season their plumage changes from brown to black and white. Adults are 24-25 cm in length with a wing length of 12-15 cm (Nelson 1997). They are most readily seen flying at dawn and dusk (Jewett et al. 1953; Alcorn 1978; WDFW 1993a; Baron and Acorn 1997).

Ecological Role. Marbled murrelets are considered opportunistic feeders and dive for small schooling fishes in clear open waters. During the breeding season, they feed primarily on fish such as sand lance, Pacific herring, surf smelt, and sea perch with sand lance being the dominant prey item (Angell and Balcomb 1982; Nelson 1997). During the winter and spring murrelets feed primarily on small crustaceans (euphausiids and amphipods), surf smelt and Pacific herring. They are also known to prey on walleye pollock, rockfish, cod, squid, and shrimp (Nelson 1997). Predators on eggs include ravens, Steller's jays, mice and squirrels. Chick predators include ravens, Steller's jays, and sharp-shinned hawks (Nelson 1997; Masselink 1999; Marzluff et al. 1999). Known predators of nesting adults include great horned owls, peregrine falcons, Cooper's hawks, and sharp-shinned hawks. Predators on adults while at sea include peregrine falcons, bald eagles, western gulls, and northern fur seals (Nelson 1997).

Environmental Requirements. The marbled murrelet is a year-round visitor to the Puget Sound region, although its numbers are typically greater in fall and winter as many are winter residents only (Angell and Balcomb 1982). Seasonal movements consist primarily of movements from outer coastal areas to protected waters (i.e., into Puget Sound) and from inland waters to breeding areas (Nelson 1997). They have been recorded in some inland stands during all months of the year. They are most often associated with the nearshore marine environment,

primarily within 5 km of shore and in waters less than 60 m deep (Nelson 1997; Terres 1987). It has been noted that they avoid kelp beds (Jewett 1953).

Marbled murrelets may obtain prey throughout the water column, including the bottom, and most likely forage in waters less than 50 m deep (Nelson 1997). Generally, open waters of entrance channels off rocky shores or over reefs are important feeding locations (Angell and Balcomb 1982).

2.1.5 Waterfowl – Family Anatidae

The Anatid family includes swans, geese, and ducks. Male and female swans and geese are similar in appearance while male ducks are colorful and females are brown. All waterfowl have webbed feet, narrow pointed wings, and most have long necks. Most have long flat bills with serrated edges to filter small plants and animals from the water. Most are gregarious, monogamous, and migratory. The harlequin duck belongs to the sea duck Tribe *Mergini* (Parker 1982; Yates 1998).

Harlequin Duck – *Histrionicus histrionicus*

Life History. On the west coast, harlequin ducks are distributed from Alaska to northern California and are residents in Puget Sound. Harlequin ducks use fast-flowing rivers and streams for breeding (and occasionally estuarine areas), and then migrate to coastlines where they occupy shallow intertidal zones (Robertson and Goudie 1999). They are diving ducks and will flip over cobbles and rocks in search of prey, but will also dabble at the surface in search of insects (Robertson and Goudie 1999). Harlequins are typically 33-46 cm in length with a wingspread of 66 cm and the males are slightly larger than females (Angell and Balcomb 1982; Robertson and Goudie 1999). Males have very distinctive breeding plumage. The females lay their eggs (5-10) in riparian zones of upland streams. The incubation time is approximately 30 days, with about 40-60 days to fledge (Ehrlich et al. 1988; Terres 1987). The females travel downstream with the juveniles to join the males in the Sound for the winter; typically October to May (Angell and Balcomb 1982; Alcorn 1978; Baron and Acorn 1997). The life span is not known but one banded harlequin duck was estimated to be a minimum of 10 years old (Robertson and Goudie 1999).

Ecological Role. While on breeding grounds, harlequin ducks feed on aquatic insects and fish eggs. On wintering grounds in marine waters, they feed on intertidal and subtidal marine invertebrates, particularly crabs, amphipods, barnacles and snails, at depths between 10-20 m. Other prey items include chitons, echinoderms, limpets, and mussels. They occasionally feed on small fish (sculpins and gunnels) and fish eggs (herring, salmonids, and suckers) on wintering grounds (Robertson and Goudie 1999). Juveniles feed on same prey items as adults but will also feed on some algae and seeds (Robertson and Goudie 1999).

Predators include bald eagles and mustelids (mink and river otters), which have been known to prey on ducklings and nesting females. Ducklings and nesting

females are also vulnerable to predation by hawks and great horned owls. Egg predators include ravens, mink, and possibly squirrels (Robertson and Goudie 1999).

Environmental Requirements. Harlequin ducks require the freshwater of rivers and streams for breeding and rearing of juveniles in early spring (Jewett et al. 1953; Yates 1998). After breeding, the males and nonbreeding females gather in small groups on rocky Puget Sound shores through the summer. In winter, they gather in small groups in the nearshore environment and in Washington, are often found in less than 1.5 m of water over eelgrass and kelp communities (Robertson and Goudie 1999). They are also associated with cobble and rocky nearshore areas as they have the ability to dive and turn over rocks in search of invertebrate prey. They dive most frequently in shallow waters but are good swimmers and may dive to at least 20 m. These birds roost on open water farther from shore at night (Robertson and Goudie 1999).

2.2 Salmonids

Seven species of salmonids will be included in the HCP. These include chinook, chum, coho, and sockeye salmon, bull and cutthroat trout, and steelhead.

Members of the family Salmonidae are medium to large fish and are powerful swimmers. They have a small dorsal adipose fin that distinguishes this family from all other fish except smelts. Most salmon and trout in the Pacific Northwest are anadromous (live most of their life in salt water but return to freshwater to spawn). There are some salmonid species and runs that are not anadromous and spend their entire life in freshwater; e.g., Kokanee and cutthroat trout. Sexual dimorphism is pronounced at spawning time with changes in color and with males developing large canine teeth, a hooked jaw, and a "razor back." Spawning adult females dig shallow depressions in the gravel beds of streams and lay small round eggs for males to fertilize. Pacific salmon die soon after spawning but some sea run trout, steelhead and bull trout can return for multiple yearly spawning. After 2-5 months the eggs hatch from the gravel. Pink and chum salmon migrate downstream immediately after hatching; chinook, coho, and steelhead remain in the stream for 6 months to two years; and sockeye move to lakes for their first 1 to 2 years. Juvenile members of the family Salmonidae use estuaries to transition into saltwater and to feed and grow (Yates 1998). Salmonids are highly migratory and most feed in the ocean for several months to several years before returning to their native rivers to spawn (Pearcy 1992).

In general, the marine phase of salmonid life history is not as well understood as the freshwater phase. Only recently have ocean environmental conditions been considered an important factor to be considered in the management of salmon resources (Bisbal and McConnaha 1999). Historically, the ocean was assumed to be an unlimited resource for salmon production, but this assumption is now being widely questioned. The suggestion that the first few months of marine rearing

can be a critical period of mortality is not new (Healey 1980). Information on marine rearing by juvenile salmon is sparse and derived primarily from purse seine, trawl, and beach seine sampling. The period of residence within "inside waters" (e.g., Puget Sound or Strait of Georgia) is variable among the different anadromous salmonids and even within a species. For example, ocean-type chinook tend to spend more time rearing in inside waters compared to larger stream-type chinook. Some coho and chinook individuals that locate sufficient food sources remain within inside waters for their entire marine rearing phase or have limited migrations (Sandercock 1991). Healey (1980) also suggested there is a tendency towards resource partitioning based upon fish size and preferred forage type. Salmon that enter marine waters as fry (pink, chum, ocean-type chinook) or that prefer smaller foods (sockeye) tend to stay in shallow estuarine and nearshore waters and feed on copepods, amphipods, and invertebrate eggs. In contrast, coho and stream-type chinook that enter marine waters as larger fish prey upon larger invertebrates and other fish (Healey 1980).

Migration patterns are one of the better-understood aspects of the marine life history phase. Most Pacific salmon stocks have a tendency to migrate in a northerly direction after entering the ocean. Chinook and coho salmon usually remain within the confines of the continental shelf. In contrast, pink, chum, steelhead, and sockeye salmon may migrate long distances to feed in pelagic regions of the North Pacific Gyre off the coast of Alaska. During the spring and summer of their last year in marine waters, maturing adults navigate towards their natal rivers for spawning. A number of mechanisms have been proposed that allow salmon to find their home stream including both celestial and magnetic orientation (Quinn and Dittman 1990). As fish approach their streams, olfaction begins to take over, and they ultimately find their natal streams following odors imprinted during their early life history (Quinn and Dittman 1990).

Pacific salmon primarily use surface waters during their marine phase—usually depths less than 50 m (CATAG 1999; Burgner 1980; Ichihara and Nakamura 1982; Healey 1980). Ultrasonic tracking of fish has revealed detailed data on their homing, migration, and rearing in the open ocean. In the open ocean, sockeye, pink, coho, chum, and steelhead swim at the shallowest depths, usually less than 10 ms, while chinook swim somewhat deeper, between 20 and 40 m (CATAG 1999). However, brief dives may occur to 150-200 m in depth (CATAG 1999). Depths used by returning sockeye and steelhead within inside waters are also shallow and appear to be related to the depth of the thermocline/halocline (Quinn et al. 1989; Ruggerone et al. 1990).

Bull Trout – *Salvelinus confluentus*

Life History. The bull trout is a char native to the Pacific Northwest and western Canada. The taxonomic distinction between bull trout and Dolly Varden (the other native char in the Pacific Northwest) has been debated although the two chars are genetically distinct and are currently considered two separate species (King County 2000a). Bull trout exhibit four distinct life history patterns: stream-resident, fluvial, adfluvial, and anadromous (McPhail and Baxter 1996).

Stream-resident, fluvial, and adfluvial forms complete their entire life cycle in freshwater while anadromous forms spend a portion of time in saltwater. There are several drainages in Puget Sound where anadromous bull trout are known/thought to occur, including Hood Canal, Skykomish River, Skagit River, Green River, and Cedar River watersheds (WDFW 1998). The Skagit River supports the largest natural population of anadromous bull trout/Dolly Varden in Puget Sound (WDFW 1998).

Bull trout mature at five to seven years of age with spawning in Puget Sound streams and rivers peaking in September and October. Fry emerge from the streambed in late winter to early spring and juveniles grow in the stream for two to three years, but this time may be shorter dependent upon life history strategy (King County 2000a). All bull trout forms may spawn repeatedly and can live as long as 12 years (Rieman and McIntyre 1993). The anadromous form is the least studied of all the bull trout forms and information regarding time spent in the marine environment is lacking.

Ecological Role. Adult bull trout are opportunistic feeders with food habits reflecting their life history strategy. Freshwater forms feed on salmon, trout, sculpins, kokanee, and steelhead fry (Rieman and McIntyre 1993). Anadromous forms feed primarily on fish such as salmon, trout, whitefish, yellow perch, and sculpins (63 FR 31693). Observations of adult char (both bull trout and Dolly Varden) in northern Puget Sound marine waters indicate feeding on bait fish (smelt, Pacific herring, Pacific sand lance) and pink salmon smolts (Kraemer 1994). Juveniles of all forms feed on terrestrial and aquatic insects, zooplankton, amphipods, mysids, and crayfish (Rieman and McIntyre 1993). Once juveniles reach a length of approximately 110 mm, they feed on small fish such as sculpins, whitefish, and trout fry (McPhail and Baxter 1996). Information on bull trout predators was scarce but may include warm-water species such as bass, centrarchids (sunfish), and perch (WDFW 1998).

Environmental Requirements. Water temperature is thought to be the most important habitat feature limiting the distribution and abundance of this species. Bull trout are uncommon in freshwater environments where water temperatures exceed 15 °C for more than a few days per year (King County 2000a). Both juvenile and adult bull trout have been found to be associated with coarse substrates such as gravel, cobble, and boulders. Larger fish tend to congregate in deeper pools, particularly those containing large woody debris or undercut banks (King County 2000a).

Anadromous adults begin downriver migration after spawning from late fall to early winter and enter estuarine waters in the spring. They remain in estuarine waters until early to mid-summer then move upriver (WDFW 1998). Anadromous smolts migrate in the spring (April to June) to river mouths and nearshore estuarine areas then return to the lower river areas in the fall, where they overwinter in the lower river (Kraemer 1994). The smolts then move into estuarine waters in late winter and early spring and will remain in these waters until starting their spawning migration in late May to July (Kraemer 1994,

WDFW 1998). Information regarding water depth and nearshore usage for both juveniles and adults in estuarine waters is lacking.

Chinook Salmon – *Oncorhynchus tshawytscha* — juveniles

Life History. Although life history strategies for chinook salmon are complex and diverse, there are two main life-history types: stream-type and ocean-type. The stream-type remains in freshwater for a year or more before migrating to ocean waters and the ocean-type migrates to ocean waters within one year (Myers et al. 1998). Most chinook in coastal areas, including Puget Sound, are the ocean-type, which reside in estuarine waters longer than the stream-type. Juveniles may reside up to 189 days in estuarine waters although data for residence times in nearshore areas are lacking (Wallace and Collins 1997).

Ecological role. There are two broad categories of juvenile chinook feeding. The first category is nearshore feeding fish that consume mainly gammarid amphipods, other epibenthic crustaceans, and terrestrial (neustonic) insects. The second category is pelagic feeding fish that feed as small juveniles on planktonic crustaceans (primarily euphausiids, as well as shrimp and crab larvae, planktonic amphipods, and copepods) and as larger juveniles on herring and other fish (Simenstad and Cordell 2000; Myers et al. 1998; see Appendix A).

Predators on juvenile chinook salmon include other salmonids, sculpins, and a variety of birds (Emmett et al. 1991).

Environmental Requirements. Important habitat for chinook salmon in Puget Sound includes intertidal and shallow subtidal areas that contain high abundances of prey items used by chinook juveniles, including harpacticoid copepods and gammarid amphipods (Simenstad and Cordell 2000). Important habitats probably include intertidal mud flats as well as areas of high detritus buildup. Based on beach seine catches, it is believed that juvenile chinook are oriented to shallow water depths located close to shore. The actual depth distribution has not been studied. Juvenile chinook are found in greatest numbers in channels and shallow waters near estuarine and tidal marshes, eelgrass meadows, and over tideflats, but are also known to occur near kelp forests and seaweed beds (C. Simenstad, Univ. of Wash., pers. comm.). Although not well studied, it is believed that the juveniles generally are found in areas with low tidal surge and wave energy (Simenstad and Cordell 2000).

Juveniles migrate along the shorelines of estuaries and the nearshore zone, where they are known to feed and rear young. Estuarine residence times vary with geographic distribution and can range from 1 to 60 days (Shreffler et al. 1990) but may be up to 189 days (Wallace and Collins 1997). During estuarine residence, the fish can move both downstream and upstream, perhaps driven by tidal dynamics in the system.

Chinook Salmon – *Oncorhynchus tshawytscha* — adult

Life History. Chinook salmon can be found from southern California to the Bering Sea. They mature in three to six years and return to spawn in larger Puget Sound streams in spring and fall. In Puget Sound, the spring-run chinook typically return to freshwater in April and May and spawn from August to September. Summer-run chinook return to freshwater from June to July and spawn in September. The fall-run chinook begin to return to freshwater in August and spawn between late September to January (Myers et al. 1998). Most adult chinook weigh less than 23 kg but individuals weighing 57 kg have been recorded (Emmett et al. 1991).

Ecological Role. Adult chinook are carnivorous opportunistic feeders. They feed primarily on fishes, including northern anchovy, scorpaenids, Pacific herring, Pacific sand lance, and euphasiids, decapod larvae, squid, and other invertebrates. Chinook salmon may directly compete with coho salmon for prey. Adults do not feed after entering freshwater. Adult chinook salmon are prey for marine mammals (e.g., sea lions, and Orcas). Upon entering freshwater chinook fall prey to eagles, bears, and other mammals (Hart 1980; Emmett et al. 1991; Kruckeburg 1995).

Environmental Requirements. Eggs and alevins require spawning gravel or cobble; freshwater juveniles are found over all substrates; saltwater juveniles in estuaries are found over mud, sand, gravel, and eelgrass; and marine adults do not show a preference for any substrate type. Adults inhabit the nearshore and estuaries. Chinook adults spawn in deeper water (generally main river channels) than other salmon and require larger gravel.

Chum Salmon – *Oncorhynchus keta* — juveniles

Life History. Chum fry enter the estuary immediately after emerging from the redd, and reach the estuary at a relatively small size (30-55 mm). The migration period in Washington estuaries is between January and July, with a peak from March to May (Emmett et al. 1991). Chum migration slows once the fish are in the estuary where they may remain for up to several months. When they reach a fork length of about 80-100 mm, chum salmon move offshore to feed on zooplankton.

Ecological role. Similar to chinook, chum salmon depend on two major habitats for feeding. In the spring when they are small, they feed primarily on the epibenthic harpacticoid copepods *Harpacticus* spp. and *Tisbe* spp. (Cordell 2000, Appendix A). Food web linkages at this stage have been presumed to be detritus based, but may also include some epibenthic primary production organisms (e.g., diatoms). At this time, they also feed on epibenthic aquatic insect larvae such as chironomids. In late spring to early summer, chum salmon switch to feeding on planktonic primary consumers such as larvaceans and copepods. In the summer, they feed on larger zooplankton such as euphausiids, hyperiid amphipods, and fish larvae (Johnson et al. 1997; Cordell 2000, Appendix A).

Predators on chum salmon include other salmonid species, particularly coho and cutthroat trout, sculpins, and Pacific cod, and a variety of marine birds (Johnson et al. 1997).

Environmental Requirements. Like chinook, juvenile chum are oriented to shallow water depths located close to shore. Although the depth distribution has not been studied, juvenile chum are found in greatest numbers in channels and shallow waters near estuarine and tidal marshes, eelgrass meadows, and over tideflats, but are also known to occur near kelp forests and seaweed beds (Johnson et al. 1997). Juvenile chum prefer exposed cobble and gravel beaches in nearshore areas, particularly in embayments. They school in shallow habitats during the day but disperse into smaller groups at night (Johnson et al. 1997). Estuarine residence times vary but have been documented to range from 1 to 14 days (Shreffler et al. 1990) and 4 to 32 days (Johnson et al. 1997). During estuarine residence, the fish can move both downstream and upstream, perhaps driven by tidal dynamics in the system. During their first year at sea, juveniles tend to group together and remain relatively close to shore—generally within 36 km (Johnson et al. 1997).

Chum Salmon – *Oncorhynchus keta* — adults

Life History. Chum salmon are found from Northern California to the Bering Sea and are the second most abundant and the most widely distributed salmonid in the north Pacific region. Chum salmon are anadromous and spawn in Puget Sound rivers in late fall. They are sexually dimorphic when they reach maturity between two and seven years of age. Adult chum salmon average four kg in weight (Hart 1980; Emmett et al. 1991).

Ecological role. Adult chum salmon are opportunistic carnivores and feed upon euphasiids, squids, pteropods, and fishes (Emmett et al. 1991). Orcas, harbor seals, and other mammals eat adult chum salmon. Spawning adults are eaten by large birds, including eagles and osprey, and bears. Pink salmon and chum salmon may directly compete for prey resources (Hart 1980; Emmett et al. 1991; Kruckeberg 1995).

Environmental Requirements. Chum salmon are generally highly migratory. Although most chum salmon move offshore in spring and early summer and head north to the Gulf of Alaska and other waters, some chum appear not to migrate and remain in Puget Sound. Adult chum salmon are epipelagic and prefer the bottom when in rivers and streams. Adults occur over a variety of substrates (Hart 1980; Emmett et al. 1991; Pearcy 1992).

Coho Salmon – *Oncorhynchus kisutch* — juveniles

Life History. Coho migrate as smolts from freshwater through the estuarine waters to ocean waters. By the time they reach the estuary, they are usually large enough that they are no longer dependent on benthic prey resources. The peak outmigration for juveniles, regardless of area, usually occurs in May (Weitkamp et al. 1995).

Ecological role. There is limited diet data for juvenile coho salmon. It appears that food web linkages for Puget Sound coho salmon are similar to those for chinook, with larger fish feeding on herring and other "baitfish" and smaller fish feeding on planktonic crustaceans. Coho differ from chinook in being less dependent on benthic/epibenthic habitats, as evidenced by fewer cases of diet dominated by taxa such as gammarid amphipods (Cordell 2000, Appendix A). When amphipods occurred as important prey for coho, they were often pelagic types, such as the gammarid *Cyphocaris challengeri* and the hyperiid *Parathemisto pacifica* (Cordell 2000, Appendix A).

Predators on juvenile coho salmon in estuaries include other salmonid species, sculpins, and a variety of marine birds.

Environmental Requirements. Smolts are often caught in intertidal and pelagic habitats in estuaries; however, the actual depth distribution has not been studied. Coho smolts are often found in beach seine catches collected over shallow habitats such as eelgrass meadows and tideflats. Being much larger than chinook and chum juveniles, it is assumed that they migrate through the estuary and nearshore zone rather rapidly.

Coho Salmon – *Oncorhynchus kisutch* — adults

Life History. Coho salmon are found from northern California to the Bering Sea. Coho salmon are anadromous and die after spawning. Coho salmon spawn in Puget Sound in winter. Most coho mature between 2 and 5 years (with an average of 3 years) and range from 41 to 100 cm in length (Emmett et al. 1991). Up to 5% of the native coho of Puget Sound may reach maturity within the Strait of Juan de Fuca (Hart 1980; Emmett et al. 1991; Pearcy 1992).

Ecological role. Coho eat fishes, including northern anchovy, Pacific herring, Pacific sardine, scorpaenids, and capelin. Coho are eaten by marine mammals, including harbor seals, Steller and California sea lions, and Orcas. Mammals including bears and large birds such as osprey and eagles prey upon spawning coho.

Environmental Requirements. Adult coho are primarily epipelagic, staying near the ocean surface, usually within the top 10 m (Emmett et al. 1991). They are found in ocean waters ranging from 4 to 15°C (Emmett et al. 1991). Coho are bottom oriented when in rivers and streams and can be found over a wide variety of substrates ranging from mud flats to rocks.

Cutthroat trout – *Oncorhynchus clarki*

Life History. Cutthroat trout are found from northern California to southeast Alaska and are found in most of the major rivers emptying into Puget Sound as well as the Lake Washington system (Johnson et al. 1999). The cutthroat trout has an anadromous form (referred to as coastal cutthroat) that returns to the ocean after spawning or over-wintering in freshwater. Native adults mature from 2 to 10 years of age and can reach 46 cm in length (Emmett et al. 1991). One-year-

old hatchery fish can return to freshwater to spawn. In Puget Sound, coastal cutthroat trout rarely extend further inland than 160 km and are usually found less than 100 km inland (Johnson et al. 1999).

Ecological role. Juvenile and adult cutthroat feed on northern anchovy, kelp greenling, scorpaenids, salmonids, euphausiids, mysids, and crab megalopae (Emmett et al. 1991). There is limited information about predation on cutthroat, but sculpins, salmonids, and piscivorous birds likely feed on juveniles and marine mammals prey on this species in marine waters.

Environmental Requirements. Cutthroat trout migration is not well understood, with some fish remaining close to where they entered saltwater and others documented as far as 20 miles offshore (Hart 1980; Emmett et al. 1991; Pearcy 1992). Juveniles and adults typically migrate through estuaries, although some are known to remain in the estuary. Adult cutthroat trout can be found in tidal freshwater areas of estuaries as they await favorable conditions to go upstream. Juveniles and adults can be found over a variety of substrates.

Sockeye salmon – *Oncorhynchus nerka*

Life History. Sockeye salmon are found from southern Oregon to the Bering Sea. Most spawn in streams near lakes or in lakes themselves where juveniles rear for one to three years before migrating to the ocean. In Washington waters, the lake/stream residence time is normally one to two years (Gustafson et al. 1997). River-type sockeye use lakes for rearing, migrate to ocean waters, and return to their natal lake system after spending one to four years in the ocean. Sea-type sockeye, which spawn in rivers, use lower, slow-velocity sections in rivers as juvenile rearing habitat for one to two years or migrate to the ocean after spending only a few months in freshwater (Gustafson et al. 1997). Sea-type sockeye also return to natal spawning habitat after spending one to four years in the ocean. Sockeye have a non-anadromous form (called kokanee), which reside in lakes and spawn in freshwater stream. The river and sea-type sockeye make extensive migrations, with juveniles from Washington waters initially migrating to the Gulf of Alaska staying relatively close to shore before moving to offshore waters (Gustafson et al. 1997). Adult sockeye average 64 cm in length and weigh three to four kg (Emmett et al. 1991). In the Puget Sound area, sockeye smolts outmigrate in spring to early summer with a shorter residence time in estuaries than other salmonids (Hart 1980; Emmett et al. 1991; Kruckeberg 1995).

Ecological role. In estuaries juvenile sockeye feed on fish larvae, juvenile shrimp, copepods, insects, amphipods, mysids, and euphausiids (Emmett et al. 1991; Gustafson et al. 1997). In marine waters juvenile sockeye feed near the surface, generally at dusk or at night. Ocean predators include spiny dogfish, salmon shark, salmonids, harbors seals, Orcas, Dall's porpoise, and predatory birds.

Environmental Requirements. Juvenile and adult sockeye are pelagic, but in freshwater adults are found near the bottom of streams and rivers. Sockeye

salmon are known to move near the surface at night and return to deeper waters during the day. Young sockeye use nearshore areas during northward migrations and migrate in groups (Gustafson et al. 1997). In marine waters, sockeye are found to a depth of 60 m (Emmett et al. 1991).

Steelhead Trout – *Oncorhynchus mykiss*

Life History. Steelhead are anadromous rainbow trout and are found from central California to the Bering Sea with most streams in the Puget Sound region containing steelhead populations (Pauley et al. 1986). There are two runs of steelhead trout: winter-run and summer-run. Winter-run steelhead migrate to native streams and rivers in late fall and early winter and spawn within a few months of entering freshwater, usually between late March and early May (Pauley et al. 1986). Winter-run steelhead are found in most major Puget Sound rivers. Summer-run steelhead migrate to native streams and rivers during spring and summer but do not mature and spawn until the following spring. Summer-run steelhead are found in four major rivers on the eastern side of Puget Sound: Skagit, Stillaguamish, Skykomish, and Green Rivers (Pauley et al. 1986). Juvenile steelhead spend from one to four years (usually two to three) in freshwater, then spend two to three years, occasionally four, in the ocean before returning to freshwater to spawn. Some steelhead may not die after spawning and may spawn in as many as five successive years. Adult steelhead usually weigh from two to five kg, but can weigh up to 19.5 kg (Pauley et al. 1986; Emmett et al. 1991; Kruckeberg 1995). The maximum lifespan is estimated at eight to nine years (Pauley et al. 1986).

Ecological role. In rivers and streams, juvenile steelhead feed on gammarid amphipods, small crustaceans, insects, aquatic worms, fish eggs, and small fishes (Cordell 2000). In marine waters, juvenile and adult sockeye eat fish, crustaceans, amphipods, squid, and herring (Emmett et al. 1991, Pauley et al. 1986). Predators include marine mammals, such as seals, sea lions, and Orcas and other fish (Pauley et al. 1986).

Environmental Requirements. Juveniles and adults are found in fresh and marine waters. Juveniles and adults migrate through estuaries but with a short residence time. Steelhead can tolerate a wide range of salinities and although they can live in waters from -18 to 27°C, they will move to deeper, cooler waters if local water temperatures rise. Juveniles usually move to sea from April through June (Wydoski and Whitney 1979, Emmett et al. 1991). Adult steelhead do not form schools and are found in marine waters usually in the upper 12.5 m of the water column, however, ocean distribution is not well known (Pauley et al. 1986). Washington steelhead stocks spend at least part of their ocean residency in the Alaskan gyre (Pauley et al. 1986).

2.3 Lampreys – Family Petromyzontidae

Two species of lampreys are proposed for inclusion in the HCP. These are the Pacific lamprey and the river lamprey.

Pacific Lamprey – Entosphenus tridentatus

Life History. The Pacific lamprey is an anadromous nongame fish. The Pacific lamprey can reach a length of 76 cm and spends from two to three years in the ocean before returning to spawn (Moyle 1976, Wydoski and Whitney 1979). Returning adults enter freshwater in late spring where they do not feed and die shortly after spawning. The young larval fish, called an ammocoete, of the Pacific lamprey may live in freshwater for up to six years before metamorphosing to the parasitic adult form and migrating to the ocean (Boschung et al. 1998). The juveniles remain in the river system from three to six years where they are filter feeders eating microscopic plants and some animals (Wydoski and Whitney 1979). Migrating juveniles are approximately 11 cm in length and enter the ocean during high water periods of late winter and early spring (Wydoski and Whitney 1979; Hart 1980)

Ecological Role. Adult lampreys are parasitic on fish, including salmon, while in the ocean (Wydoski and Whitney 1979; Hart 1980). The extent of damage to salmon stocks is uncertain, but as much as 20 percent of young salmon sampled have shown scars from lamprey parasitism (Wydoski and Whitney 1979). As well as being parasitic, lampreys are also scavengers and predators and have been known to prey on marine mammals (Wydoski and Whitney 1979; Hart 1980). Lampreys can be prey for game fishes during spawning migrations. Other predators include sperm whales, seals, crayfish, and birds (Scott and Crossman 1973; Hart 1980).

Environmental Requirements. Lampreys require low gradient sections in streams with gravel and sandy bottoms for spawning. During the juvenile stage, lampreys depend on muddy bottoms, backwater areas, and also low gradient areas (Hart 1980). As adults they migrate to the ocean. Information regarding environmental requirements for the adult life stage in marine waters was not readily available.

River Lamprey – *Lampetra ayresi*

Life History. River lampreys are distributed primarily from California to Alaska, though adult forms roam widely through the North Pacific Ocean (Wydoski and Whitney 1979; Hart 1980). River lampreys are anadromous. The biology of the river lamprey is not well understood and is assumed to be similar to the Pacific lamprey. Adult river lampreys can reach 30 cm in length and are parasitic on ocean fish and marine mammals (Wydoski and Whitney 1979). They enter freshwater streams in late spring and spawn in June and July in shallow redds excavated in fine stream gravels. The adults die after spawning. After about two months, the young hatch and drift downstream to burrow in low-energy, fine-

grained sediment deposits (e.g., backwaters) where they feed on protozoa and invertebrates (Wydoski and Whitney 1979; Hart 1980). River lamprey juveniles and smaller adults are difficult to distinguish from the Pacific lamprey. There is some evidence that they can spend all of their lives in freshwater systems that have been dammed (elib.cs.berkeley.edu).

Ecological Role. In the marine environment adults are primarily parasitic, feeding on larger fish and some marine mammals. Known predators of lampreys include fish, whales, and seals (Wydoski and Whitney 1979; Eschmeyer et al. 1983).

Environmental Requirements. River lampreys require low gradient sections in streams with gravel and sandy bottoms for spawning. During the juvenile stage, lampreys depend on muddy bottoms, backwater areas, and also low gradient areas (Hart 1980). As adults they migrate to the ocean. Information regarding environmental requirements for the adult life stage in marine waters was not readily available.

2.4 Marine Invertebrates

Two species of invertebrates are proposed for inclusion in the HCP. These species are the northern abalone and the Olympia oyster.

2.4.1 Abalones – Family Haliotidae

Abalones are large marine molluscs with a thick commercially valuable shell and edible flesh. The shell has been known to reach over 20 cm in diameter, but is more commonly around 12 cm, and has prominent holes used for water exchange (Kozloff 1983). Abalones are cosmopolitan and live from the intertidal zone to 50 m depths but are most common at deeper depths (Grzimek 1970). They use their powerful foot to hold fast to solid substrates and have a radula to scrape off algae for food.

Northern Abalone – *Haliotis kamtschatkana*

Life History. The northern abalone is found along the Pacific coast from Baja California to as far north as Sitka, Alaska (McConnaughey and McConnaughey 1985). Although commercially valuable, the shell of the northern abalone is thin compared to other abalone species. Mature northern abalones are broadcast spawners and males and females synchronize the release of gametes in the water column between April and June (Sloan and Breen 1988). After fertilization there is a brief pelagic free-swimming larval stage that lasts for approximately two to seven days, then the larvae settle to the bottom. It is thought that larval dispersal is limited to a geographic area less than 100 m (Sloan and Breen 1988). An average adult is approximately 10-13 cm in length and can live to 50 years of age (Sloan and Breen 1988).

Ecological role. Northern abalones are herbivores and typically graze at night (Kozloff, 1983; Yates 1998). Juveniles have small, weak mouthparts and are unable to exploit food sources other than coralline algae, diatoms, and bacterial films (Fallu 1991). As the juveniles develop, their predominant feeding habits shift to grazing on mostly brown algae. Predation varies throughout the life of the abalone. Species such as crab, fish (including rockfish), octopus, sea stars, and snails will prey on egg and larval stages (Sloan and Breen 1988). Developing and adult abalones can be dislodged by cabezon and swallowed whole, however, the most effective known predator, other than man, is the sea otter.

Environmental Requirements. The northern abalone is usually found on firm substrates, generally rocks, in areas of moderate water exchange, such as exposed outer coasts (Sloan and Breen 1988). They can occur from the lower intertidal zone down to a subtidal depth of over 100 m, but in Puget Sound they are found almost exclusively in subtidal areas at water depths between 10 to 15 m (Kozloff 1983; Yates 1998; McConnaughey and McConnaughey 1985). Generally, northern abalones do not occur in estuaries and in Puget Sound inland waters; they have not been observed south of the Keystone ferry dock on central Whidbey Island (R. Anderson, Seattle Aquarium, pers. comm.).

2.4.2 Oysters - Family Ostreidae

Oysters are common bivalves with eight North American species and two species in the Pacific Northwest. Adult oysters can reverse sexes and can produce up to 500,000 larvae per year (Conte et al. 1994). The eggs of oysters are fertilized and develop within the mantle cavity. Once they are released into the water column, the larvae attach to hard substrates, including oyster shells, and develop into mature oysters. Oysters are filter feeders and generally live submerged in salt waters that are relatively free of turbidity (Parker 1982; Yates 1998).

Olympia Oyster – *Ostrea conchaphila* (Formerly *O. lurida*)

Life History. The Olympia oyster is a small native oyster rarely exceeding 5 cm in length and is found along the northern Pacific coastline from Baja, California to southern Alaska, although not in abundance (Kozloff 1983). In Washington State, Olympia oysters grow slowly and reach their maximum lengths in approximately three years, but their maximum lifespan has not been determined (Couch and Hassler 1989). The Olympia oyster initially spawns as a male then alternates its functional gender between each spawning cycle. Spawning occurs at water temperatures between 13 to 16°C (Couch and Hassler 1989). Fertilized eggs are brooded in the mantle cavity for 10-14 days and then are released as larvae (Haderlie and Abbott 1980). The larvae swim for 30-40 days, develop an eyespot and a foot for crawling onto hard substrates, and then metamorphose into spat. For settling surfaces, the spat have a preference for the underside of rocks and old oyster shells (Conte et al. 1994; McConnaughey and McConnaughey 1985).

Ecological role. Similar to other bivalves, the Olympia oyster is a filter feeder with planktonic algae as its principal staple throughout all life stages; however, some nutrients can be derived from detritus, micronutrients in solution, and other materials (Conte et. al. 1994). The known natural predators of the Olympia oyster are sea stars and diving ducks (such as scaups and scoters), although predation from introduced Japanese oyster drills, *Ocenebra japonica*, the flatworm *Pseudostylochus ostreaophagus*, and the copepod *Mytilicola orientalis* has also impacted Olympia oysters (Cook et al. 1998). The red rock crab, *Cancer productus*, is an important predator throughout much of the Olympia oyster's range and is a common crab in Puget Sound (Couch and Hassler 1989). Other factors that affect Olympia oyster populations are competition for space by the Pacific oyster (*Crassostrea gigas*) and substrate disruption caused by burrowing ghost and mud shrimp and smothering by slipper shells (Cook et al. 1998).

Environmental Requirements. The Olympia oyster resides in intertidal and subtidal marine habitats including the underside of rocks, mud flats, bays, gravel bars, and on pilings (Kozloff 1983; McConnaughey and McConnaughey 1985). They occur in tidal channels, bays, and in estuaries (Couch and Hassler 1989). These oysters are sensitive to extreme high and low temperatures but can tolerate salinity fluctuations (Couch and Hassler 1989). Olympia oysters occur in inland Puget Sound waters but are abundant only in Case Inlet and southern Puget Sound (Cook et al. 1998).

2.5 Marine Fish

Twenty-four species of marine fish are proposed for inclusion in the HCP. The covered species include six species of ground fish, four species of forage fish, and 14 species of rockfish.

2.5.1 Ground Fish

Six species of ground fish will be included in the HCP. These include two sturgeon, three true cod, and lingcod.

Family Acipenseridae

There are approximately 25 species of sturgeons, but only two species occur in the Pacific Northwest (green and white sturgeons) (Delacy and Borton 1972). Acipenseridae are characterized by elongate and fusiform body shapes with 5 rows of bony plates on the back, middle of each side, and each side of the belly. The bony plates of juveniles are sharp but become smooth as the fish age to the point of disappearing in very old individuals. The head is bony, and the snout is long with four barbels in front of the mouth. There are no teeth in adults. The caudal fin is forked; only one dorsal fin is present.

In the Pacific Ocean, sturgeons are found off eastern Asia (Japan, Korea, and Russia) and from northern Baja, Mexico to the Gulf of Alaska (Hart 1980). All

sturgeons spawn in freshwater, but some species are anadromous. In marine waters, sturgeons are found in bays and estuaries at the mouths of large coastal rivers. Sturgeons feed primarily on bottom organisms, including worms, molluscs, crustaceans, and small fish (Eschmeyer et al. 1983). Sturgeons are fished recreationally and commercially in Washington coastal rivers and estuaries (Columbia River, Willapa Bay, Skagit River, and Grays Harbor). The white sturgeon is considered more valuable than the green sturgeon for the quality of its meat. Roe is also collected. Sturgeons are often incidentally caught in gill nets during the salmonid fishing season. An average of 4.7 and 15.9 tons of green and white sturgeon, respectively, are landed each year in Grays Harbor and Willapa Bay (Emmett et al. 1991).

Green Sturgeon – Acipenser medirostris

Life History. Spawning generally occurs in spring and early summer for green sturgeons occurring in California and Oregon (Emmett et al. 1991). Gravid females have been caught in the Columbia River in the fall, but no life history data exist for sturgeon present in Puget Sound. Individual females probably do not spawn each year. Green sturgeons broadcast spawn on substrate ranging from sand to bedrock in areas where freshwater is flowing relatively fast. Spawning most likely occurs in water depths greater than 3 m (Emmett et al. 1991). Eggs adhere to the substrate after fertilization. Little data are available for the larval and juvenile stages of green sturgeons. From data collected on white sturgeons, green sturgeon larvae may be 8-19 mm in length when hatched. It is presumed that juveniles range from 2 cm to 1.5 m in length (Emmett et al. 1991). Juveniles are also benthic feeders, but large juveniles may feed on epibenthic invertebrates and small fish. Sturgeons mature late in life. Among white sturgeons, maturity ranges from 11 to 34 years of age. The maximum lifespan of green sturgeon is unknown. A green sturgeon caught in Klamath River was estimated to be 60 years old. Adults can attain lengths over 2 m and weights of 136 kg or more (Emmett et al. 1991).

Ecological Role. Sturgeons largely prey on benthic invertebrates; however, large juveniles and adults will also feed on epibenthic invertebrates and small fish (Emmett et al. 1991). A wide range of fish species likely preys upon sturgeon eggs, larvae, and juveniles. Large adults have few predators other than humans and large marine mammals (Emmett et al. 1991).

Environmental Requirements. Green sturgeons must exist in areas where freshwater rivers, having relatively rapid flow rates, open into estuaries and embayments. Juvenile sturgeon stay in the lower, freshwater areas of large coastal rivers (i.e., San Joaquin River, Klamath River) and then migrate to estuaries before they are two years old (Emmett et al. 1991). Migration typically occurs during the summer and fall months. As they grow, juveniles will migrate from freshwater deltas and estuaries into nearshore subtidal waters where they will reside as adults. Adult green sturgeons spend limited time in freshwater and reside in subtidal marine waters. In Oregon and Washington, green sturgeons rarely move far up rivers or estuaries. Spawning generally occurs in spring and

early summer (Emmett et al. 1991). However, green sturgeons have been shown to travel great distances. Fish tagged in the Sacramento-San Joaquin estuary have been caught in the Columbia River and in Grays Harbor one to three years later. Occurrences of green sturgeons in the Strait of Juan de Fuca have been reported for adults only, and the occurrences are rare.

White Sturgeon – Acipenser transmontanus

Life History. The white sturgeon is anadromous but is capable of completing its life cycle in freshwater (i.e., fish landlocked by dams) (Emmett et al. 1991). Like the green sturgeon, the white sturgeon spawns in large, freshwater rivers but, unlike the green sturgeon, adults can spend a great deal of time in both marine and freshwater. Females do not spawn annually, but probably every 3 to 5 years (Emmett et al. 1991). Spawning occurs during the spring in rivers with relatively high flow rates. White sturgeons are highly fecund broadcast spawners and spawn in areas with large cobble and boulder substrate. Eggs adhere to the substrate after fertilization. Larvae range in length from 8 to 19 mm and begin active feeding approximately 12 days after hatching. Young juveniles may be 20 mm in length and grow to 1.2 m or longer before maturing (Emmett et al. 1991). Growth and maturity tend to vary among west coast estuaries, but all sturgeons are slow growing and mature late in life. In Oregon, the females mature at approximately 15 years of age (1.7 m in length), while the males mature earlier and are shorter (Emmett et al. 1991). The maximum age of the white sturgeon is not known but may exceed 100 years. Some adults exceed weights of 800 kg and can reach lengths of 6 m (Emmett et al. 1991).

Ecological Role. Juveniles and adults are benthic carnivores. Juveniles prey on benthic and epibenthic invertebrates, including amphipods, shrimp, bivalves, and insect larvae (Emmett et al. 1991). Large juveniles and adults will feed on amphipods, clams, *Crangon* shrimp, ghost shrimp, mud shrimp and other benthic invertebrates (Emmett et al. 1991). They will also feed on fish, including eulachon and northern anchovy. A wide range of fish species likely preys upon sturgeon eggs, larvae, and juveniles. Humans catch large adults, while some may be eaten by large marine mammals (Emmett et al. 1991).

Environmental Requirements. Larvae and young juveniles are riverine, while older juveniles and adults are riverine, estuarine, and marine. River flow is important for the effective movement of juveniles downstream. The older life stages are largely spent in riverine and estuarine habitat, generally in subtidal areas. However, the white sturgeon has been observed feeding in intertidal areas at high tide (Emmett et al. 1991). Small juveniles have been observed in shallow freshwater locations of the San Joaquin Delta and deep-water channels of the Columbia River. White sturgeons occur on a variety of sediment types, ranging from sandy silt and clay to coarse sand and gravel. General movement patterns exist among juvenile and adult white sturgeons but no migration has been noted (Emmett et al. 1991). Large adults move upstream to spawn in late winter and spring and downstream in fall and winter. Some white sturgeons have been tracked between California and Washington, but most white sturgeons do not

move these great distances (Emmett et al. 1991). Occurrences of white sturgeons in Puget Sound are rare, however, they have been observed in the Strait of Juan de Fuca, Port Orchard, the Seattle area, and southern Puget Sound (Delacy and Borton 1972).

Family Gadidae

Gadidae, generally termed codfishes, includes true cods, hake, pollock, and haddock. There are about 75 species, but only four species occur in the Pacific Northwest. Of these, three species are proposed for inclusion in the HCP: Pacific hake, walleye pollock, and Pacific cod.[2] They are moderate in size, elongate, and have small cycloid scales. In the Northwest, codfishes have well-formed, square caudal fins, two or three dorsal fins, and one or two anal fins. The pacific cod have chin barbels. Codfishes generally live on or near the bottom feeding on prey such as crabs, molluscs, and fish.

Pacific Cod – Gadus macrocephalus

Life History. Pacific cod form large spawning aggregates in shallow waters during the late winter. Pacific cod are broadcast spawners, and large females can produce millions of eggs. Eggs of the Pacific cod sink to the sea floor where they adhere to fine-grained sediments and particulates. In Puget Sound, cod spawn in shallow water embayments, such as Port Townsend Bay and Agate Passage (Wilson et al. 1994, West 1997). Depending on temperature, eggs develop into larvae in 8-21 days. Cod larvae are 3-4 mm in length and occur both near the bottom and in the water column, rising to water depths of 15-30 m (West 1997). It takes several months for larvae to achieve the juvenile form. By late summer, juveniles settle in a relatively shallow, demersal habitat, typically in eelgrass beds. Pacific cod reach maturity at 2 to 3 years of age, ranging from 40 to 70 cm in length and 1-4.5 kg in weight (Hart 1980). Large females may reach a length of 100 cm. Due to natural predation and other factors, Pacific cod seldom live beyond age six.

Ecological Role. Juvenile cod are bottom feeders, preying on crabs, shrimp, snails and fish (flatfish, zoarcids, stichaeids, cottids, pricklebacks, eelpouts, and walleye pollock) (Wilson et al. 1994). Adult Pacific cod feed on euphausiids, shrimp, and both benthic and pelagic fishes, including sand lance, herring, and other species (Lamb and Edgell 1986; West 1997).

Environmental Requirements. Pacific cod are found in a variety of habitats generally in water depths of 50-200 m (Wilson et al. 1994). Juveniles tend to inhabit areas of eelgrass with a sandy substrate. Adults are demersal, and can be found over fine to coarse-grained substrate. After spawning, adult cod disperse to deeper waters where they feed during the remainder of the year. The distribution of this species depends on water temperature and the availability of prey. In Puget Sound, abundances decline from north sound to south sound. Three spawning populations exist in Puget Sound. One stock is located in the

[2] Hart (1980) places Pacific Hake in the family Gadidae. Others put this species in the family Merlucciidae, based on certain internal features.

Gulf of Georgia, the second occurs in the Straits of Juan de Fuca (Port Angeles, Green Point, Hein Banks) and Port Townsend Bay, and the third stock occurs south of Admiralty Inlet. Other important spawning, feeding, and nursery areas in Puget Sound are Orcas Island, Kilisut Harbor, Port Gamble, Agate Pass, Dyes Inlet, Quartermaster Harbor, Point Defiance, Point Fosdick, and Fox Island (Wilson et al. 1994). Pacific cod have been observed in Seattle and the Duwamish River (Stober and Pierson 1984).

In the 1980s, abundances of Pacific cod declined severely in Puget Sound due to a period of warm water temperatures, over fishing, and mammal predation (Wilson et al. 1994). The recreational fishery in Agate Passage and a commercial set net fishery in Port Townsend Harbor have been closed for several years. Populations in southern Puget Sound have been described as "near extinct" (Palsson et al. 1997).

Walleye Pollock – Theragra chalcogramma

Life History. Spawning aggregations of walleye pollock form from February to April in deep water. Spawning locations have been identified in Halibut Bank, Active Pass and Point Roberts, and Port Townsend Bay (Wilson et al. 1994). Eggs and larvae are pelagic and have been found at water depths between 100 and 300 m (Wilson et al. 1994). Female fecundity varies with size of the female. Females 40 cm in length may produce 200,000 eggs, while females 75 cm in length may produce 1.4 million eggs. Adult pollock range from 28 to 65 cm in length, and are thought to live to age 17 (Wilson et al. 1994). Recent data suggest that pollock may live longer than 17 years.

Ecological Role. Juvenile pollock feed primarily on crustaceans. As walleye pollock mature, they feed on small fishes, including other pollock, sand lance, and herring (Wilson et al. 1994). They themselves may be preyed upon by large mammals and historically were part of a recreational fishery.

Environmental Requirements. Juveniles become semi-demersal, moving to inshore, shallow habitats in their first year of life. They settle in areas with eelgrass, and gravel and cobble substrate. In their second year of life, juvenile pollock move back to deeper waters, occupying mid-water and near-bottom habitat near sandy or muddy substrates (West 1997, Wilson et al. 1994). In general, the species prefers cold, northern waters and is found throughout Puget Sound. Currently, there are at least two stocks of pollock in Puget Sound: one in the Strait of Georgia (Point Roberts), which has been exploited commercially from time to time, and the second in northern Puget Sound (Port Townsend, Marrowstone Island, Indian Island) (Wilson et al. 1994). Walleye pollock were once the most common species caught recreationally in Puget Sound. In the 1980's, like the Pacific cod, numbers of walleye pollock declined sharply due largely to natural mortalities and fishing pressures (West 1997).

Pacific Hake – Merluccius productus

Life History. Spawning aggregations of Pacific hake form from January through March at mid-water depths. In Puget Sound, Port Susan appears to be the primary spawning ground (Wilson et al. 1994). Eggs and larvae are pelagic. In the Strait of Georgia, the eggs occur at depths of 170 to 220 m, and eggs hatch within five days (Wilson et al. 1994). Larvae move to shallow, inshore waters where considerable growth occurs during the summer months. Fish mature and spawn at age four and may reach a maximum age of 20 years (Wilson et al. 1994). In general, commercially caught hake range from 4 to 11 years in age and from 40 to 50 cm in length.

Ecological Role. Hake larvae feed upon copepods and their eggs during the spring and early summer months. Adult Pacific hake primarily feed upon euphausiids and sand lance, and to a lesser extent herring, smelt, anchovy, and shrimp (Wilson et al. 1994). Dogfish and large mammals (sea lions, harbor seals, cetaceans) prey upon hake (Wilson et al. 1994, Hart 1980, Eschmeyer et al. 1983). Historically, Pacific hake were part of a large fishery in Central Puget Sound.

Environmental Requirements. Larvae develop in mid-water until they are large enough to move inshore and actively school. Data from the Strait of Georgia suggest that the majority of juveniles remain in inshore waters away from concentrations of adults, but juveniles can occur in mid-water depths as well (Wilson et al. 1994). There are four major spawning stocks along the west coast. Stocks occurring off California, Oregon, Washington, and British Columbia appear to be the most abundant. In Washington, other stocks occur in the Strait of Georgia and in Central Puget Sound (including the Seattle area), both are genetically distinct from the coastal stocks (Wilson et al. 1994). There may also be other discrete stocks within Puget Sound. The largest Puget Sound aggregation of Pacific hake occurs in Saratoga Passage from September through December (West 1997, Wilson et al. 1994). As juveniles mature, fish move to Port Susan and form spawning aggregations (January through March). During the remainder of the year, hake have been observed throughout Puget Sound in smaller schools.

Family Hexagrammidae

This is a small family of marine fishes that are limited in distribution to the North Pacific. They are bottom fishes typically found in shallow water (Hart 1980). One species, the lingcod, is proposed for inclusion in the HCP.

Lingcod – Ophiodon elongates

Life History. Spawning occurs once a year from mid-December to mid-March with most egg laying finished by the end of January (Shaw and Hassler 1989). Males establish territories in nesting areas and wait for females to deposit their eggs in crevices between large rocks or slightly under a boulder or rocky shelf (Shaw and Hassler 1989). Nesting areas are 3-10 m below the lowest tide level

and where there are strong currents (Shaw and Hassler 1989). Males fertilize the eggs as the female lays them and when spawning is completed the female leaves the area while the male remains to guard the eggs (Shaw and Hassler 1989). The number of eggs laid increases with increasing size of the female (Shaw and Hassler 1989). Incubation time for the eggs is probably 6-8 weeks (Shaw and Hassler 1989). Newly hatched larvae are 7-11.5 mm long and have a small yolk sac that is absorbed in about ten days (Shaw and Hassler 1989). By the end of the first year of life the juveniles average 270 mm long and are 470 mm long by the end of the second year (Shaw and Hassler 1989). Males begin to reach sexual maturity at 520 mm and females at 700 mm long (about 3-5 years) (Hart 1980). The average lifespan is 12-14 years for males and about 15-16 years for females (Shaw and Hassler 1989). The maximum length can be up to 152 cm, but is rarely more than 122 cm (Eschmeyer et al. 1983).

Ecological Role. The larvae are very active as they feed on small copepods and copepod eggs (Shaw and Hassler 1989). As they grow, their diet shifts to larger copepods, fish larvae, and larvaceans (Shaw and Hassler 1989). When they reach 70-80 mm long they begin feeding on juvenile herring and other juvenile fish (Shaw and Hassler 1989). Adult lingcod prey on a variety of fish (mainly juvenile *Sebastes* spp.), cephalopods, gastropods, and crustaceans (Shaw and Hassler 1989). Humans are the main predators of adult lingcod, while adult lingcod, rockfish, and cabezon often feed on lingcod eggs and juveniles (Shaw and Hassler 1989).

Environmental Requirements. Newly hatched larvae are carried with the plankton in the water currents (Hart 1980). When juveniles reach 70-80 mm (about two months old), they congregate in shallow, nearshore locations among seaweeds, eelgrass, and sandy bottoms (Shaw and Hassler 1989). Most adults are relatively sedentary, remaining in place on the bottom (Shaw and Hassler 1989). They move only diurnally to shallower depths with darkness and to deeper water with light (Shaw and Hassler 1989). Lingcod can be found from near-surface to depths of 475 m (Lamb and Edgell 1986), but the majority are in water less than 100 m deep (Shaw and Hassler 1989). They prefer rocky locations with considerable current (Shaw and Hassler 1989).

2.5.2 Forage Fish

Four species of forage fish are proposed for inclusion in the HCP. These species are Pacific herring, sand lance, surf smelt, and eulachon.

Family Clupeidae

Most species of this family are small (less than 30 cm long), silvery, and form schools in shallow water (Eschmeyer et al. 1983). Several groups occur in freshwater and some are anadromous (Eschmeyer et al. 1983). Straining small organisms from the water with their gill rakers is the primary feeding mode of most species, but some select individual planktonic organisms from the water and a few eat small fish (Eschmeyer et al. 1983).

Pacific Herring – Clupea harengus pallasi

Life History. At least 18 stocks of Pacific herring spawn inside Puget Sound (WDFW 1997a). These herring stocks spawn from late January to early April with the exception of the Cherry Point stock, which spawns through early June (WDFW 1997a). Small (13 mm), transparent larvae hatch after about 2 weeks and are dispersed by currents from the spawning areas (WDFW 1997a). At about three months and 38 mm in length, herring metamorphose into adult form and coloration and begin to school (WDFW 1997a, Lassuy 1989). In their second or third year, they mature and return to spawn and will continue to spawn in successive years (WDFW 1997a). Mortality rates are quite high in all life stages; adults rarely survive beyond age five (WDFW 1997a).

Ecological Role. As larvae, herring feed on zooplankton (copepods) and phytoplankton (diatoms) (Williams 1989). Copepods are the dominant prey item through metamorphosis and as juveniles (Hart 1980). The invertebrate larval communities associated with eelgrass beds are also a major food source (Lassuy 1989). The feeding habits of juveniles and adults once they move into deeper waters are not well known (Lassuy 1989). During their spawning migration and inshore spawning period, adult herring may greatly reduce or stop feeding (Lassuy 1989). Many types of organisms feed on herring eggs; they may be a particularly important food source for shoreline birds (e.g., gulls, coots, ducks) (Lassuy 1989). Herring larvae are preyed on by pelagic invertebrates (e.g., medusa) and by salmon, surfperch, and juveniles and adults of their own species (Lassuy 1989). Less is known about predation of juvenile herring as they move offshore and into deeper waters (Lassuy 1989). Adult herring are susceptible to predation by salmon, seals, sea lions, Orcas, and fish-eating birds while holding inshore before and during spawning (Lassuy 1989; WDFW 1997a). Offshore predators include Pacific hake, sablefish, spiny dogfish, Pacific cod, and salmon (Lassuy 1989).

Environmental Requirements. Most spawning takes place between 0 to –3 m in tidal elevation, although eggs have been found near the upper limits of high tide and to a depth of 12 m (WDFW 1997a). Eggs are found on firm substrates including eelgrass, algae, oyster shells, rocky-sandy bottoms, pilings, and driftwood (WDFW 1997a). Larvae, juveniles and adults occur throughout the water column although first year juveniles that move offshore tend to be found mostly at water depths between 150-200 m (Lassuy 1989). Herring do not migrate large distances, but move onshore and offshore seasonally to spawn and feed (Lassuy 1989). Adults move onshore during winter and spring to holding areas prior to moving to spawning grounds (WDFW 1997a). Adults consistently return to their natal spawning grounds to reproduce and there are known spawning sites in central Puget Sound (Lassuy 1989; WDFW 1997a).

Family Ammodytidae

Species of this family occur in nearshore and offshore surface waters of the North Pacific, North Atlantic, and Indian Oceans (Eschmeyer et al. 1983). There are

about twelve species but only one occurs along the Pacific Coast of North America (Eschmeyer et al. 1983).

Sand Lance – Ammodytes hexapterus

Life History. Spawning occurs once a year from November to February primarily in inshore areas (WDFW 1997b). The eggs incubate for about four weeks before hatching (WDFW 1997b). Larvae are about 5 mm long upon hatching and are planktonic until reaching about 22 mm in length when they become semi-demersal and start schooling (WDFW 1997b, Auster and Stewart 1986). Sexual maturity is reached at 1-3 years of age (Emmett et al. 1991). Maximum lifespan is about 8 years (Emmett et al. 1991).

Ecological Role. The larval diet includes diatoms, dinoflagellates, copepods, and copepod nauplii (Emmett et al. 1991). With increasing size, juveniles and adults remain plankton feeders but eat larger organisms (Emmett et al. 1991). Diving birds, gulls, seals, and sea lions prey on adult sand lance and they are a significant component in the diet of many fish (e.g., juvenile salmon, Pacific cod, Pacific hake, and dogfish) (Emmett et al. 1991; WDFW 1997b). Humans occasionally harvest sand lance for sport bait (WDFW 1997b).

Environmental Requirements. Spawning occurs at tidal elevations from +1.5 m to about the mean higher high water line on sand to gravel beaches (WDFW 1997b). There are documented sand lance spawning areas throughout Puget Sound, including the central basin (Penttila 1995). During deposition a coat of sand grains adhere to the eggs and may help with moisture retention when the eggs are exposed during low tide (WDFW 1997b). Juveniles rear in bays and nearshore waters (WDFW 1997b). The adults often school near the surface in open water during the day and burrow into sand at night to avoid predation but little is known regarding sand lance movements (WDFW 1997b).

Family Osmeridae

Species of this family are only present in the Northern Hemisphere (Eschmeyer et al. 1983). Most occur in temperate to subarctic marine waters, but a few are anadromous or landlocked in freshwater (Eschmeyer et al. 1983).

Surf Smelt – Hypomesus pretiosus

Life History. Spawning in Puget Sound occurs during much of the year and perhaps year-round (WDFW 1997c; Lemberg et al. 1997). Eggs incubate for 2-5 weeks before hatching (WDFW 1997c). Larvae are about 3 mm long upon hatching and are planktonic for about three months when they reach about 30 mm in length (WDFW 1997c). Sexual maturity is reached by the second year, but a small proportion will spawn in the first year (WDFW 1997c). Surf smelt are schooling fishes and have a maximum lifespan of about five years (WDFW 1997c).

Ecological Role. Diet consists of planktonic organisms, including crustaceans, comb jellies, and fish larvae (Williams 1989). Surf smelt eggs, juveniles, and

adults experience high levels of predation. Seabirds, marine mammals, and other fishes all prey on adult surf smelt (WDFW 1989). In Washington State, humans take about 100,000 pounds annually in commercial fisheries (WDFW 1997c).

Environmental Requirements. Spawning occurs at a tidal elevation between +2 m and the mean higher high water line on mixed sand to gravel beaches (WDFW 1997c). Juveniles rear in nearshore waters (WDFW 1997c). Adults school offshore and seem to return to the same spawning ground each year (WDFW 1997c). There are documented surf smelt spawning areas throughout Puget Sound, including the central basin (Penttila 1995). Information was not readily available regarding offshore movements and water depths when schooling offshore.

Eulachon – Thaleichthys pacificus

Life History. Eulachon is an anadromous species found from northern California to the southern Bering Sea (Hay 1999). Spawning occurs in most freshwater rivers once a year during the late winter/early spring (Hart 1980; Lamb and Edgell 1986; Bargmann 1998). Spawning occurs earliest in the Columbia River in January and February and one of the rivers with the latest spawning in April to May is the Fraser River (Hay 1999). A high level of adult mortality follows spawning but it is unknown if all of the adults die (Hart 1980; Bargmann 1998). Eggs, which are small (<1 mm), demersal and adhesive, incubate for 30-40 days before hatching (Hart 1980, Hay 1999). Newly hatched larvae are 5-7 mm long and rapidly drift out to marine waters (Hart 1980). Sexual maturity is reached at three or four years at a length between 108 and 135 mm (Hart 1980). Adults that survive spawning may reach ages well beyond four years (Hart 1980). This species is considered rare in Puget Sound (Emmett et al. 1991).

Ecological Role. Larvae eat phytoplankton and small zooplankton (Emmett et al. 1991). Juveniles and adults eat planktonic crustaceans such as euphausiids and copepods (Hart 1980). The eulachon spawning migration attracts many predators, such as dogfish, sturgeon, halibut, cod, marine mammals, and gulls (Hart 1980). Salmon and other fish feed on the eulachon larvae and juveniles (Hart 1980).

Environmental Requirements. Adults spend most of their lives in the Pacific Ocean and return to silty rivers, like the Columbia River, for spawning during the spring (Emmett et al. 1991). Spawning timing and locations within rivers appears to be influenced by water temperature, current, and turbidity (Bargmann 1998). Adults spend the majority of time close to the bottom but little information regarding water depth range was readily available.

2.5.3 Rockfish

Fourteen species of rockfish are proposed for inclusion in the HCP. In the following sections, information common to all species is presented first, followed by specific information for each individual species.

Family Scorpaenidae

This is the largest family of Scorpaeniformes in the Northeastern Pacific and includes members in the genus *Sebastes* (rockfish) (Eschmeyer et al. 1983). Probably all species of rockfish are venomous (Stein and Hassler 1989). The venom is produced in poison glands associated with some or all of the fin spines (Stein and Hassler 1989). The venom of most Northeastern Pacific species is painful but not dangerous unless an allergic reaction is provoked (Stein and Hassler 1989).

The spawning habits and early life history of individual rockfish species are not well described because the larvae and juveniles are very difficult to identify (Stein and Hassler 1989). Spawning probably occurs once a year, but may occur more than once in some species (Stein and Hassler 1989). Spawning of the various rockfish species occurs sequentially rather than simultaneously, with black rockfish being the earliest spawners (J.Christiansen, Seattle Aquarium, pers. comm.). The females' fecundity increases with increasing size (Stein and Hassler 1989). All species of rockfish have internal fertilization and bear live young (Hart 1980, Stein and Hassler 1989). The newly released larvae spend about two months in the water column feeding on small zooplankton (Stein and Hassler 1989). When the planktonic larvae reach a specific size they recruit to shallow, benthic, nursery habitats (West 1997). Studies of the more common species (copper, quillback, and brown rockfish) indicate that shallow areas with eelgrass, kelp beds, and other vegetation on cobbles and boulders are utilized as nursery habitats (West 1997). Upon reaching adult size, they move to adult habitats (usually rocky reefs, boulders, offshore pinnacles, and other hard, high relief substrates) where they will remain relatively sedentary for many years (as many as 20 years for some species) (West 1997).

Although many rockfish species occur together, they have evolved to avoid competition for limiting resources, such as food, by ecological specialization (Stein and Hassler 1989). Each species, while having similar general preferences for food and habitat, focuses on a small subset of available prey or habitat structure that is not as well utilized by the other co-occurring rockfish species. In general, rockfish are opportunistic carnivores and will eat many animals, including small fish, crustaceans, polychaetes, and molluscs (Stein and Hassler 1989; Williams 1989). As juveniles, rockfish are eaten by many species of fish, including other rockfish, lingcod, wolf eels, and cabezon (Stein and Hassler 1989). Rockfish are found in bays along shore, in kelp beds, and offshore to about 450 m (Eschmeyer et al. 1983).

Brown Rockfish – Sebastes auriculatus

Life History. Spawning occurs once a year (Stein and Hassler 1989). Eggs mature during the winter, followed by ovulation and fertilization in March and April (Stein and Hassler 1989). Embryos develop quickly and are released from April to July (Stein and Hassler 1989). Larvae are 5-6 mm long at birth (Stein and Hassler 1989). Sexual maturity is reached by 225-260 mm long (about three

years) (Stein and Hassler 1989). The maximum lifespan is unknown but individuals can reach at least 19 years of age and grow up to 550 mm long (Stein and Hassler 1989).

Ecological Role. Crabs and shrimp are the major component in the diet of adult brown rockfish, which also includes small fish, isopods, and polychaetes (Stein and Hassler 1989).

Environmental Requirements. The juveniles, 37-50 mm long, hide in crevices of hard substrates in shallow nearshore waters (Stein and Hassler 1989). They are often around piers and in bays and use estuaries as nursery grounds (Stein and Hassler 1989). Adults are found in shallow water, bays, and offshore to 128 m (Eschmeyer et al. 1983). They are solitary and tend to stay near the bottom in rocky areas with caves and crevices (Stein and Hassler 1989; J. Christiansen, Seattle Aquarium, pers. comm.).

Copper Rockfish – *Sebastes caurinus*

Life History. Spawning occurs once a year (Stein and Hassler 1989). Eggs mature during the winter and are ready for fertilization sometime between February and May (Stein and Hassler 1989). Fertilization occurs from March to May following ovulation (Stein and Hassler 1989). Parturition occurs as early as April (Lamb and Edgell 1986; Stein and Hassler 1989). Larvae are 5-6 mm long at birth and are pelagic until they are 40-50 mm long (Stein and Hassler 1989). Males reach sexual maturity by 300-400 mm long (3-7 years) (Stein and Hassler 1989). All females are mature by 410 mm long (about eight years) and many are mature by 366 mm long (about four years) (Stein and Hassler 1989). Maximum lifespan is at least 20 years (Stein and Hassler 1989). Maximum length is 570 mm (Eschmeyer et al. 1983; Lamb and Edgell 1986). This is one of the most common rockfish species found in Puget Sound, particularly south Puget Sound (J. Christiansen, Seattle Aquarium, pers. comm.).

Ecological Role. The copper rockfish diet consists of benthic crustaceans, fish, and molluscs (Stein and Hassler 1989). Copper rockfish smaller than 45 mm long eat primarily calanoid copepods, harpacticoids, and zoea (Stein and Hassler 1989). Amphipods, shrimp, caprellids, and other small crustaceans form the diet of 110-155 mm copper rockfish (Stein and Hassler 1989). As they grow, they become increasingly aggressive feeders, preying mostly on fish (Stein and Hassler 1989). Like most rockfish, the juveniles are prey for many other fish species (Stein and Hassler 1989). Seals and other large predators probably eat the adults (Stein and Hassler 1989).

Environmental Requirements. The small, pelagic juveniles hide in surface and mid-depth kelp canopies (Stein and Hassler 1989). Individuals larger than 40-50 mm long become benthic and hide in the relief of hard substrates such as rocks and barnacles (Stein and Hassler 1989). The juveniles may also use bays as nurseries (Stein and Hassler 1989). Mature fish do not move far once they have chosen a "home" location (Stein and Hassler 1989). The adults are almost

always in contact with the bottom and choose substrates of rock or rocky sand (Stein and Hassler 1989).

Greenstriped Rockfish – *Sebastes elongates*

Life History. Parturition occurs in late spring or early summer (Hart 1980). Larvae are about 5 mm at birth (Hart 1980). Adult length can reach 380 mm (Eschmeyer et al. 1983).

Ecological Role. Diet is probably opportunistic like most *Sebastes* species. Juveniles and small individuals probably suffer predation from other fish.

Environmental Requirements. Adults prefer deep (91-366 m) (Hart 1980), level, mostly sandy or silty bottoms (Lamb and Edgell 1986).

Widow Rockfish – *Sebastes entomelus*

Life History. Parturition occurs during later winter (Hart 1980; Lamb and Edgell 1986). Sexual maturity is reached at 3 or 4 years of age at a length of about 320 mm (Hart 1980; Lamb and Edgell 1986). Adult length can reach 530 mm (Hart 1980). This species is uncommon in Puget Sound and is found most often offshore on the outer coasts in aggregations (J. Christiansen, Seattle Aquarium, pers. comm.).

Ecological Role. Diet includes plankton and small fish (Hart 1980).

Environmental Requirements. Adults stay in the water column (probably in schools) above deep (91-366 m) (Hart 1980), rocky reefs or steep shorelines (Lamb and Edgell 1986).

Yellowtail Rockfish – *Sebastes flavidus*

Life History. Parturition occurs during late winter (Hart 1980; Lamb and Edgell 1986). Newly released larvae are about 4.5 mm long (Hart 1980). Sexual maturity is reached at about 5 years of age at a length of about 330 mm (Hart 1980). Adult length can reach 660 mm (Hart 1980). Adults of this species can be found throughout central Puget Sound and are resident year-round in Elliott Bay. Juveniles are typically seen only in the Strait of San Juan de Fuca and the waters surrounding the San Juan Islands in July and August (J. Christiansen, Seattle Aquarium, pers. comm.).

Ecological Role. Diet includes small fish, crustaceans, and squid (Hart 1980).

Environmental Requirements. Adults form schools in shallow (26-46 m), open water (Eschmeyer et al. 1983) along steeply sloping shores or above rocky reefs (Lamb and Edgell 1986). Juveniles are also seen in open water at relatively shallow depths less than 35 m (J. Christiansen, Seattle Aquarium, pers. comm.). Limited information was readily available regarding movements of this species, but it does appear that juveniles and adults inhabit different areas within Puget Sound and the outer Straits (J. Christiansen, Seattle Aquarium, pers. comm.).

Quillback Rockfish – *Sebastes maliger*

Life History. Parturition occurs around May (Matthews 1987; Williams 1989). Sexual maturity is reached at about 4 years of age (Matthews 1987). Adult length can reach 610 mm (Hart 1980).

Ecological Role. Diet includes amphipods, crabs, shrimp, snails, and small fish (Williams 1989).

Environmental Requirements. Adults prefer rocky reefs and hard, even bottoms of inlets around 15 m deep, but have been found down to 275 m deep (Hart 1980; Lamb and Edgell 1986). This species is usually found at or near the bottom and tends to be solitary (J. Christiansen, Seattle Aquarium, pers. comm.). Information concerning juvenile habitat and movements was not readily available.

Black Rockfish – *Sebastes melanops*

Life History. Spawning probably occurs once a year and may occur in offshore waters (Stein and Hassler 1989). Eggs develop as early as August (Stein and Hassler 1989). Parturition occurs from February to April and probably as early as January (Stein and Hassler 1989). Larvae are about 5.5 mm long at birth and are pelagic until they are 40-50 mm long (Stein and Hassler 1989). Males reach sexual maturity at sizes between 250 and 430 mm long (about 3 to 10 years) (Stein and Hassler 1989). Females are mature by 300-480 mm long (about 5-11 years) (Stein and Hassler 1989). Maximum lifespan is at least 21 years (Stein and Hassler 1989). Maximum length is 600 mm (Eschmeyer et al. 1983).

Ecological Role. As a midwater species, adult black rockfish avoid competition for food with most other rockfish and eat primarily pelagic nekton (smelt, anchovies, squid) and zooplankton such as salps, mysids, and crab megalops (Stein and Hassler 1989). However, the benthic juveniles must compete with other benthic species and tend to decrease in abundance as the abundance of other species increases (Stein and Hassler 1989).

Environmental Requirements. The small, pelagic juveniles swim in open water or hide in large, offshore kelp beds (Stein and Hassler 1989). As the juveniles grow larger than 40-50 mm long, they move inshore, often to eelgrass beds in estuaries, tide pools, and nearshore depths of less than 20 m (Stein and Hassler 1989). Adults form schools in midwater over kelp-covered rocky reefs to depths of 360 m or more (Lamb and Edgell 1986). However, they are most abundant in waters less than 54 m deep (Stein and Hassler 1989).

Blue Rockfish – *Sebastes mystinus*

Life History. Parturition occurs in winter (Hart 1980). Sexual maturity is reached at 3 to 5 years of age (Hart 1980). Adult length can reach 530 mm (Hart 1980). This species is not found in inland Puget Sound and only occurs on the outer Washington Coast and outer Straits (J. Christiansen, Seattle Aquarium, pers. comm.).

Ecological Role. Diet includes tunicates, jellies, and fish (Hart 1980).

Environmental Requirements. Adults form schools over deep (183-550 m) (Hart 1980), rocky reefs (Eschmeyer et al. 1983).

China Rockfish – *Sebastes nebulosus*

Life History. Little is known other than the general life cycle of the genus. Adult length can reach 430 mm (Hart 1980). This species rarely occurs in inland Puget Sound and is found in nearshore waters from 10 to 50 m along the outer Washington coast and Straits (J. Christiansen, Seattle Aquarium, pers. comm.). China rockfish, particularly juveniles, are often mistaken for other rockfish species.

Ecological Role. Diet is probably opportunistic like most *Sebastes* species. Juveniles and small individuals probably suffer predation from other fish.

Environmental Requirements. Adults prefer shallow (less than 92 m), exposed rocky shores or reefs where they can take shelter in crevices when disturbed (Hart 1980). Adults are solitary and territorial and will often remain at a particular site for years (J. Christiansen, Seattle Aquarium, pers. comm.). Information regarding juveniles was not readily available.

Tiger Rockfish – Sebastes nigrocinctus

Life History. Tiger rockfish can be found from Alaska to central California but they are not common, if found at all, in inland Puget Sound waters (J. Christiansen, Seattle Aquarium, pers. comm.; W. Palsson, WDFW, pers. comm.). Little is known other than the general life cycle of the genus. Adult length can reach 610 mm (Hart 1980). The larva of this species tends to settle out with drift kelp. Tiger rockfish are often antagonistic to other fish and are solitary and territorial (J. Christiansen, Seattle Aquarium, pers. comm.).

Ecological Role. Diet is probably opportunistic like most *Sebastes* species. Juveniles and small individuals probably suffer predation from other fish.

Environmental Requirements. Adults prefer rocky reefs between 10 and 275 m deep (Lamb and Edgell 1986) where they can take shelter in a home crevice that they will aggressively defend (Hart 1980).

Bocaccio – Sebastes paucispinus

Life History. This species occurs from Alaska to southern California but bocaccio are not often seen in inland Puget Sound waters as adults prefer deep waters (J. Christiansen, Seattle Aquarium, pers. comm.). Spawning occurs twice a year with parturition occurring in November and again in March (Hart 1980). Newly released larvae are 4-6 mm long and are pelagic until they reach a length of about 30 mm (Hart 1980). Sexual maturity is reached at 3 or 4 years of age at a length of about 360 mm (Hart 1980). Adult length can reach 910 mm (Hart 1980).

Ecological Role. Diet includes small fish (Hart 1980).

Environmental Requirements. The pelagic larvae occupy the upper mixed layer of water (Hart 1980). Juveniles of about 30 mm in length move into shallow water (Hart 1980). Adults prefer open water adjacent to deep (73-300 m) reefs (Hart 1980; Lamb and Edgell 1986). Although the habitat of juvenile bocaccio is not well known, they most likely are found in nearshore areas (W. Palsson, WDFW, pers. comm.).

Canary Rockfish – *Sebastes pinniger*

Life History. This species occurs from Alaska to southern California but does not occur in inland Puget Sound waters. In Washington, canary rockfish occur along the outer coast and through the Straits (J. Christiansen, Seattle Aquarium, pers. comm.). Parturition occurs in January or later (Hart 1980). Sexual maturity is reached at 5 or 6 years of age at a length of about 350 mm (Hart 1980). Adult length can reach 760 mm (Hart 1980). In the Straits, larvae settle out in June to July at a water depth of 5 m or less (J. Christiansen, Seattle Aquarium, pers. comm.).

Ecological Role. Diet is probably opportunistic like most *Sebastes* species. Juveniles and small individuals probably suffer predation from other fish.

Environmental Requirements. Adults prefer rocky bottoms of various depths to 360 m and possibly deeper (Lamb and Edgell 1986). Juveniles inhabit shallower waters and often school just above the bottom (J. Christiansen, Seattle Aquarium, pers. comm.).

Redstripe Rockfish – *Sebastes proriger*

Life History. Little is known other than the general life cycle of the genus. Adult length can reach 610 mm (Hart 1980).

Ecological Role. Diet is probably opportunistic like most *Sebastes* species. Juveniles and small individuals probably suffer predation from other fish.

Environmental Requirements. Adults prefer areas deeper than 25 m where rocky reefs and steep silt-covered cliff faces meet gently sloping sandy or muddy bottoms (Lamb and Edgell 1986). Little information is known about this species except that both juveniles and adults usually inhabit deep waters.

Yelloweye Rockfish – *Sebastes ruberrimus*

Life History. This species occurs from southern California north to Alaska and is fairly common at deeper depths in inland Puget Sound (J. Christiansen, Seattle Aquarium, pers. comm.). Parturition occurs in June (Hart 1980). Adult length can reach 910 mm (Hart 1980).

Ecological Role. Diet includes fish (gadids, sand lance, herring, juvenile rockfish), crabs, shrimp, and snails with shrimp being the predominant prey (Williams 1989; J. Christiansen, Seattle Aquarium, pers. comm.).

Environmental Requirements. Adults prefer steep-faced rocky reefs, offshore pinnacles, and boulder fields at depths below 14 m (Lamb and Edgell 1986; Williams 1989). Large adults usually inhabit depths deeper than 30 m and are solitary and tend to hide in crevices and recesses (J. Christiansen, Seattle Aquarium, pers. comm.). Information regarding juvenile habitat use was not readily available.

2.6 Habitats Evaluated

A wide variety of habitats can be found in and along the shorelines of King County. These range from exposed beaches where wind driven waves have created coarse grained shallow subtidal and littoral habitats to inner Elliott Bay where sediment from the Duwamish River has created muddy, shallow subtidal regions. On the north and south sides of points (e.g., West, and Alki Points) and headlands (e.g., Duwamish Head) gyres created by wind and tidal driven currents allow particulate material to settle out of the water column to the seafloor, providing food for benthic infaunal communities.

Each of the three primary areas discussed in this report (i.e., the Brightwater Outfall Siting Area; the WTD Existing Discharge Area; and the Vashon Island area; see Section 1.2) have been divided for discussion purposes into four basic habitat zones. These include the following:

Photic Zone

- Supralittoral: >+ 3 meters mean lower low water (MLLW)
- Intertidal: -1 to +3 meters MLLW
- Shallow Subtidal: -30 to -1 meters MLLW

Aphotic Zone

- Deep Subtidal: > -200 to -30 meters MLLW

Below the major features and vegetation associated with each habitat zone is discussed. In addition, information is summarized on the types of marine animals that are often associated with these habitat zones. The intertidal and shallow subtidal zones are discussed together as they are both part of the marine photic zone.

2.6.1 Supralittoral

The supralittoral zone (i.e., the zone immediately above the intertidal zone) can be referred to as the marine "riparian" zone. Vegetation in this zone includes trees and shrubs, dune grasses, and other salt tolerant vegetation (Dethier 1990). It is at this elevation where erosion protection structures are most often located to protect the adjacent upland property. The ecological functions of this zone have

not been documented in detail. The vegetation provides shade in the upper intertidal zone, which is believed to be important for protecting surf smelt and sand lance eggs deposited high on beaches (D. Penttila, WDFW, pers. comm.). The vegetation probably moderates temperature and minimizes desiccation. New information indicates that insects produced in the riparian zone are frequently found in the stomachs of juvenile salmon that migrate nearshore (Simenstad and Cordell 2000). For purposes of discussion in Sections 3, 4, and 5, we have limited the types of riparian conditions to natural vegetated areas including trees and dunes, and modified shorelines including riprap, concrete and other structures.

2.6.2 Intertidal – Shallow Subtidal

Intertidal-shallow subtidal zone habitats include rocky and soft substrata and vegetation. The zone extends from -1 MLLW down to the depth at which macroscopic benthic plants are no longer found (i.e., the photic zone). At least 157 species of benthic algae have been reported from the central Puget Sound area (Thom et al. 1976). The upper elevations on rocky shorelines are generally characterized by rock weed (*Fucus distichus*), which is a relatively stable component of the rocky shore habitats (Dethier 1990). It is known to harbor amphipods that are often found in the guts of juvenile salmon (C. Levings, Canada Dept. of Fisheries and Oceans, pers. comm.). Mid and lower intertidal rocky areas are characterized by sea lettuce (*Ulva* spp.), and soft brown algae such as *Laminaria* spp. (Thom et al. 1976). They can be extremely productive, fixing and transporting large amounts of carbon to the nearshore ecosystem (Thom and Albright 1990). The shallow subtidal zone in rocky areas also contains kelp forests (*Nereocystis luetkeana*). Although annual in nature, the kelp forests are often sites where adult and juvenile fishes (especially rockfish) congregate.

Sand and mud flats in the region can have floating sea lettuce in the intertidal and shallow subtidal zone (Thom and Albright 1990). They also contain productive microalgal communities. These microalgal communities are known to support abundant prey resources (i.e., harpacticoid copepods, amphipods) for juvenile chum and chinook salmon as well as English sole and Dungeness crab (Thom et al. 1989; Simenstad et al. 1991). Shorebirds and water fowl such as dunlin, least sand pipers, spotted sand pipers bufflehead, common goldeneye, great blue heron, greater yellowlegs, and horned grebe can heavily feed on vegetation and prey on flats (Simenstad et al. 1991). The sand flats are often dominated by bivalve sand clams (*Macoma* spp.) (Armstrong et al. 1976).

Eelgrass (*Zostera marina*) is a rooted angiosperm that forms meadows in the low intertidal and shallow subtidal zone in the region (Thom and Hallum 1990). Eelgrass meadows harbor large number of fish taxa, and often contain juvenile Dungeness crab and salmonids in very high numbers. Together, eelgrass meadows and tideflats form an extremely important feeding and rearing habitat

dawsoni, *Solaster stimpsoni*, *Pycnopodia helianthoides,* and *Crossaster papposus,* as well as the five rayed sea star *Mediaster aequalis* (EHI 1985). The dominant benthic infauna is highly dependent on sediment grains size but generally consists of polychaete *Phyllochaetopterus prolofica*, the ostracod *Euphilomedes carcharodonta*, and the bivalve mollusc *Psephedia lordi* (Word et al. 1981; Striplin et al. 1985; Striplin et al. 1993).

In many parts of Puget Sound very little information is available about slope depths (~60 to ~150 m) because of the difficulty in sampling. This includes many locations in the study area where the slope exceeds 45 degrees, making using of standard samplers extremely difficult (Word et al. 1984a). In areas where surveys can be easily conducted (i.e., outer Elliott Bay), the sediments consist of sand with various amount of silt, depending on the slope. In areas with fairly steep slopes, the sediments consist of silt, often overlying hard clay (Word et al. 1984a). In areas with slopes less than 45 degrees, the dominant large epibenthic invertebrates appear to be *Mediaster aequalis* at the shallow end of the depth range and sea stars in the genus *Luidia* at greater depths. The sea anemone *Metridium senile* also appears in this depth range and extends to water depths in excess of 200 meters (Striplin et al. 1985). The sea whip *Acanthoptilum* spp. begins to appear in the mid portion of the depth range. In areas where very steep slopes are found (i.e., East Passage) very little information is available. The Seahurst Baseline Study conducted in the early 1980s sampled slopes in the East Passage of the Sound (Word et al. 1984a). They found that in water depths of ~ 120 to 150 meters the slopes consisted of silt which appeared to be somewhat stabilized by the large cigar-shaped tubes of polychaetes in the genus *Asychis*. Also captured in some grab samples were the sea stars *Pycnopodia helianthoides*, *Luidia* spp., and the sea whip *Acanthoptilum* spp. The dominant infaunal invertebrates in areas with silty sand were the bivalve molluscs *Crenella decussata*, *Macoma alaskana*, *Nemocardium centifilosum* and the polychaetes in the genus *Prionospio*. At the base of the slopes the dominant infauna were polychaetes in the genera *Prionospio* and *Myriochele*, the bivalve mollusc *Axinopsida serricata*, and ostracods in the genus *Euphilomedes*.

The slope of Puget Sound generally flattens out at water depths of 150 meters. In these water depths the sediments consist of silt with clay. The exceptions to this general rule can be found at the bases of points (i.e., West, Alki, Three Tree Point) where bottom currents are swift enough that fine silts will not settle (Word et al. 1984a, 1984b). Very few large epibenthic invertebrates were found in these water depths during a video survey conducted in 1985 by Evans-Hamilton, Inc. (EHI 1985). The most obvious invertebrate seen in the video footage was the sea whip *Acanthoptilum* spp. Also present, but not seen in video footage, was the burrowing echinoderm *Brisaster latifrons*. This echinoderm is frequently captured in grab samples in large abundance. The dominant infauna at these deep basin depths is also dependent on grain size, however in siltier sediments (approximately 95% of the basin area), the dominants include polychaetes in the genera *Spiophanes*, *Ampharete*, and *Pectinaria*. Dominant molluscs include *Macoma carlottensis* and *Axinopsida serricata;* dominant crustaceans are

Euphilomedes producta and *Eudorella pacifica* (Word et al. 1984a, 1984b; Tetra Tech 1990; Striplin et al. 1990, 1991, 1993).

The distribution of fishes other than the HCP species in the deep subtidal was well documented by Donnelly et al. (1984) during the Seahurst Baseline Study. Using multivariate analysis on fish data collected from several locations and depths over a two-year period he noted that the groupings of offshore demersal fish were primarily determined by water depth and secondarily by season. The largest diversity of fish were found in the 50 and 100 m depth intervals while the community found at the 200 m interval was the least diverse. The most abundant species at the 50 m depth interval included six species of flatfish and five species of roundfish. Four species of flatfish and five of roundfish were most abundant at the 100 m depth interval while three flatfish and two roundfish species were predominant at the 200 m interval.

The distribution of fishes ranked by abundance and water depth are summarized below.

Fish Species		Water Depth		
Common Name	Scientific Name	50 m	100 m	200m
Slender sole	*Lyopsetta exilis*	✔	✔	✔
Dover Sole	*Microstomus pacificus*	✔	✔	✔
Rex sole	*Glyptocephalus zachirus*	✔	✔	
Pacific sanddab	*Citharichthys sordidus*	✔		
Rock sole	*Lepidopsette bilineata*	✔		
English sole	*Parophrys vetulus*	✔	✔	✔
Plainfin midshipman	*Porichtys notatus*	✔	✔	
Roughback sculpin	*Chitonotus pugetensis*	✔		
Shiner Perch	*Cymatogaster aggregata*	✔		
Pacific tomcod	*Microgadus proximus*	✔		
Walleye Pollock	*Theragra chalcogramma*	✔	✔	✔
Ratfish	*Hydrolagus colliei*		✔	✔
Spiny dogfish	*Squalus acanthias*		✔	
Blackbelly eelpout	*Lycodopsis pacifica*		✔	

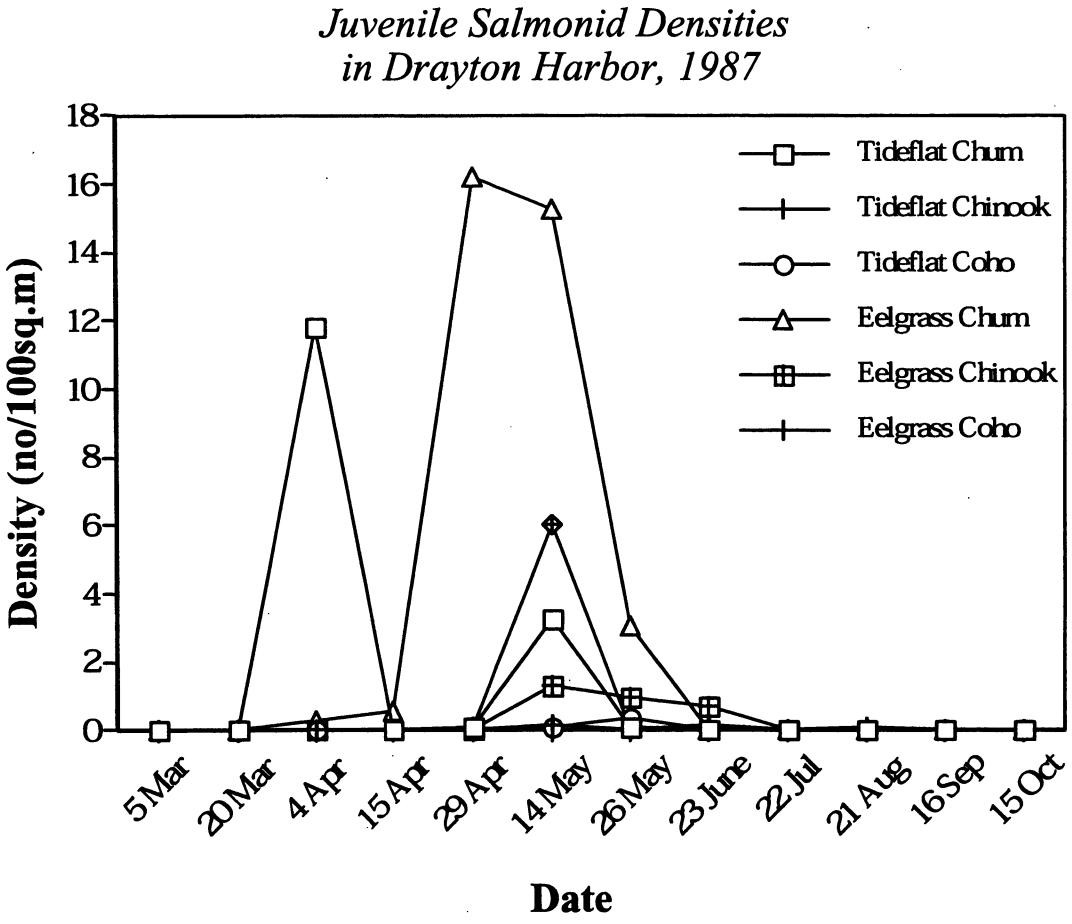

Figure 2-1. Densities of chinook and coho salmon in Drayton Harbor associated with tideflat and eelgrass habitat types